GRAZING STUDY in the MISSOURI BREAKS

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GRAZING STUDY in the MISSOURI BREAKS

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Determination of the best system for grazing a range is one of the major concerns of range managers. A. W. Sampson (1913, 1914) was one of the first to suggest a system of deferred-rotation grazing and to outline some basic principles of grazing management. Since these early attempts to establish systems of grazing based on sound biological principles, a vast amount of new information has been accumulated. This information includes descriptions of the natural or climax vegetation for an area, the responses of individual plant species to grazing, and the requirements of each species for reproduction and maintainance of vigor. The development of new systems for maintaining or improving range condition has progressed as new information becomes available.

Despite a long history of research on grazing practices, range managers continue to search for the best grazing system. Wambolt (1973) stated that no single grazing system is best under all conditions. Therefore, each must be tested to determine which conditions it is best suited for.

Various grazing systems have been established on public lands in the Missouri River Breaks area for a number of years. Allotments on which these systems were established offer a unique opportunity to evaluate the merits of each system. During the summer of 1977 we studied the impact of the planned grazing system on each of eleven allotments. The objective of the study was to assess the impact of each grazing system on vegetation and soils within each allotment. These impacts were compared to those exerted by different schedules of grazing on the same soil and vegetation types in adjacent sites or pastures. Specific objectives were to determine

the influence of each grazing system on:

1. Plant species composition and range condition,
2. Plant production,
3. Vigor of one or more key forage species on each site,
4. Accumulation of litter on the soil surface,
5. Seedling establishment, and
6. Soil composition.

METHODS

Bureau of Land Management personnel selected eleven grazing allotments for study. Each allotment was on BLM land in the Missouri River Breaks area. Allotment names, grazing system for each, number of years each system has been in operation, and acreage in each are summarized in Appendix 1. The systems include season-long grazing (1), 2-pasture deferred-rotation (1), 3-pasture rest-rotation (3), 4-pasture rest-rotation (2), 5-pasture rest-rotation (3) and 6-pasture rest-rotation (1). Allotments ranged in size from 6,738 acres to 25,160 acres.

The large size of each allotment and short amount of time available to assess each prevented use of the entire acreage in our study. Therefore, within each allotment we selected sites to be studied which were representative of the influence of the grazing system on the entire acreage. Twenty-seven sites were selected within the eleven allotments.

Information about the vegetation and soil conditions at one point in time on a site or within an allotment does not by itself provide an indication of the impact or relative merit of the grazing system. If data are collected on conditions on the site at the time the grazing system is established, then changes in these parameters can be measured at some

later time, and the influence of that particular system can be assessed. Since little or no data were collected on each allotment before each grazing system was established, we only had access to the data which we collected after the system had been in effect for a number of years. Therefore, we used fence-line contrasts to compare the soils and vegetation within an allotment to those outside the allotment. By knowing the past grazing treatment of the site on each side of the fence, we were able to contrast the influence of the grazing system to that of another grazing treatment. It is then possible to compare a 4-pasture rest-rotation system to season-long grazing, a 2-pasture deferred-rotation system to season-long grazing, etc.

The decision to use fence-line contrasts to compare different grazing treatments dictated the location of sample sites on the perimeter of each allotment. Sample sites were located only at locations where the soils, aspect, percent slope and potential plant community were the same. Each site was also located so that distance from water would not be a factor. It was assumed, then, that the only factor which would cause any difference in conditions on both sides of the fence would be past grazing use. Because of the need to establish sites under these conditions, we found the random location of sample sites an impossibility. Therefore, we drove or walked the perimeter of each allotment and selected sample sites which met our pre-established criteria.

Past grazing history within and outside of each allotment was obtained from BLM Allotment Management Plan (AMP) files and from conversing with individuals knowledgeable of the past grazing. Other information was obtained from AMP files where appropriate. Local Soil Conservation

Service offices were contacted to obtain existing soil survey data, and range site and condition guides.

Data collection included plant species composition (percent by weight), total plant production per acre, plant vigor, pounds of litter per acre, seedling establishment, and soil infiltration. Range condition was calculated from the plant species composition data. Comparable data were collected on each side of the fence.

Plant Species Composition

Ten sample plots each 9.6 square feet in area were randomly established on each side of the fence. The weight (grams) of each plant species in each plot was estimated and converted to pounds per acre. The percent that each species contributed to the total weight in that plot was calculated to establish the species composition. Data from the ten plots were averaged to determine the percent composition for the site. Accuracy of the estimates to within 5% of the actual weights was attained by estimating weights within a practice plot, then weighing the plants until the desired accuracy in estimating was reached.

Plant Production

Total plant production (pounds/acre) was determined as the sum of estimated weights in a plot. The mean production was calculated from the ten plots.

Range Condition

The S. C. S. method of expressing range condition was used. This method allowed not only the determination of the condition class (excellent,

good, fair, poor), but also a numerical rating of the condition. Thus, the range on both sides of the fence might be in the same condition class, but the numerical rating shows which is actually in better condition. Range site and condition guides provided by the S. C. S. were used. Data from the percent plant composition were used to calculate range condition.

Litter

Weight of litter present in each plot was calculated in the same manner as weight of live plant material. Estimates of litter were averaged over the ten plots to calculate a mean for the site.

Seedling Establishment

Seedlings for each plant species were counted in each of the plots and averaged for the site. Seedling establishment is assumed to provide some information about regeneration of those species that depend on seeds for reproduction. These data provide no information about regeneration of those species that mostly reproduce vegetatively.

Plant Vigor

Plant vigor is a measure of the health of a plant. It denotes the relative appearance, vitality, rate of growth, and herbage production of a plant. It is a composite expression of the influence of all environmental factors which influence growth, including grazing. Whenever ranges are overgrazed, deterioration is often first reflected in a decline of plant vigor (Joint Committee 1962).

Any measurement of plant vigor is only an indication of the plant's health, since health is a relative characteristic and cannot be measured

directly. It then becomes necessary for the researcher to determine the characteristic of a plant which is the best measure of vigor. Short and Woolfolk (1956) observed plants in eastern Montana on ranges in different condition classes. They suggested that plant height is a valid measure of vigor and that vigor, so measured, is an important criterion for classifying range conditon.

The heights of leaves, length of twigs, number of flower stalks, and amounts of seeds produced are commonly-used measurements of vigor. However, all the factors that influence vigor are integrated in herbage production. Thus, if an individual herbaceous plant can be identified, the weight of the plant is the best measure of its vigor (Joint Committee 1962).

Bostick (1947) established methods of measuring plant vigor. For grasses, the measurements include plant height, leaf length and herbage weight. For shrubs, leaf size, twig length, twig mortality, and production of fruit and flowers were suggested.

Vigor was measured for one or sometimes two key species on each site. Since several life forms were represented among the key species, it was necessary to determine the best vigor measurement for each species. The following measurements were used:

Poa secunda	seed stalk height
Agropyron smithii	leaf length
Atriplex nuttallii	leaf area
Bouteloua gracilis	leaf length
Calamagrostis montanensis	leaf length
Koeleria cristata	height of vegetative growth
Stipa viridula	height of vegetative growth
Agropyron spicatum	plant weight, number of seedstalks
Stipa comata	height of vegetative growth

Soil Infiltration Rates

Infiltration is the downward movement of water through the soil surface and soil mass. The rate of infiltration of water into the soil influences the amount of precipitation that enters the soil and the amount that leaves the site as runoff. The differential influences of grazing systems on the soil within the short time that the systems have been established would be restricted to soil compaction, which in turn influences infiltration rates.

Lodge (1954) found that heavy grazing on mixed prairie ranges having loam and silt loam soils at Swift Current, Saskatchewan, resulted in soil compaction and reduced soil moisture holding capacity. Thus, those plant species that grow better under drier conditions are favored in competition.

The Joint Committee (1962) described the use of the double-ring infiltrometer to measure infiltration rates. The apparatus consists of a pair of concentric rings driven one to two inches into the soil. Water is placed inside both rings at the same level, and measurements of water depth are taken from the inner ring. It is assumed that the water in the outer ring forms a wetted zone which serves as a buffer to reduce lateral movement of water from the inner ring.

Infiltration rates were measured at six randomly located points on each side of the fence at a site. Infiltration was measured at five-minute intervals for fifteen minutes, and was calculated as mm/minute for each five-minute interval.

LITERATURE REVIEW

Natural Vegetation of the Region

Before the present condition of a range can be evaluated, it is necessary to determine what the natural or climax vegetation would be if the range were undisturbed. Characterization of climax on the northern Great Plains would have to include grazing as a natural part of the ecosystem. Bison undoubtedly had a major influence on the character of the Great Plains plant communities before livestock were introduced. They overgrazed certain areas of the grasslands, but their wandering nature would probably have resulted in their leaving the area for "greener pastures", and not returning for an extended period of time. During this time, the range would recover (England and DeVos 1969). Thus, intense grazing followed by deferment or rest seems to have existed on the grasslands.

Larson (1940) suggested that the Great Plains was formerly grazed heavily by bison and other animals which held the western plains in a short grass state. After an extensive review of the early records of travelers and scientists who observed the northern plains region, he concluded that: 1) the former population of wild animals stocked the plains to carrying capacity so that the introduction of livestock only served to replace one group of grazers with another; 2) the short grass plains existed long before livestock were introduced; and 3) the marked ability of the short grass dominants to withstand grazing indicates that this environmental factor is not new to the region.

England and DeVos (1969) mentioned an account provided by the diary of David Thompson which recorded a statement by the Piegan Indians that

the bison sometimes grazed during the summer and fall along the Missouri River until the ground was essentially bare and the bison could no longer live there.

Several attempts have been made to describe the natural vegetation of eastern Montana and surrounding areas. Hanson and Whitman (1938) sampled 36 sites in the vicinity of Sentinel Butte and Medora in western North Dakota, in an unglaciated portion of the plains. The sites were mostly located in winter-grazed pastures, in ungrazed portions of land adjoining cropland and in lightly grazed pastures. They concluded that the grassland community on upland plateaus and gentle upland slopes is dominated by Bouteloua gracilis, Stipa comata and Carex filifolia. Agropyron smithii and Koeleria cristata are found in greater amounts in lower successional stages and are subdominants in the climax. The Artemisia cana type was restricted to flats along streams and in valleys.

Wright and Wright (1948) studied the grassland types of south central Montana. They reported that the mixed prairie type occupies clay and silt loam east of the mountains and is dominated by Bouteloua gracilis, Stipa comata and Koeleria cristata. It is apparently similar to the Stipa-Bouteloua type of southern Canada, although Bouteloua gracilis may contribute more to total production in the warmer climate of south central Montana.

Coupland (1950) described the natural plant communities of the mixed prairie in southern Canada. The Stipa-Bouteloua communities occur on medium-textured soils deposited upon undifferentiated glacial till deposits. The type occurs to a limited extent on soils of undulating topography developed on glacial outwash. This type is postclimax to the Bouteloua-Stipa type, and is found around Swift Current. The dominants include

Bouteloua gracilis, Stipa comata, and Stipa spartea; subdominants are Agropyron smithii, Koeleria cristata, Carex filifolia and Agropyron dasystachyum, and the secondary species include Poa secunda, Stipa viridula and Poa cusickii.

The Bouteloua - Stipa communities, common around Manyberries, Alberta, occur on soils of medium texture developed on undifferentiated glacial till deposits in the drier areas, where conditions are less favorable for mid grasses. This type is dominated by Bouteloua gracilis, with an interspersion of Stipa comata. Artemisia cana is the most conspicuous shrub, while Artemisia frigida and Phlox hoodii are the most important forbs. Dominant grasses are Bouteloua gracilis and Stipa comata; subdominants include Koeleria cristata, Agropyron smithii, Carex filifolia and Agropyron dasystachyum; while other species of lesser importance include Poa secunda, Sporobolus cryptandrus, Artemisia frigida, Artemisia cana, Phlox hoodii, Sphaeralcea coccinea and Eurotia lanata.

The Agropyron smithii subtype occurs on slightly alkaline clay flats and on certain alluvial clay flats. It is often the sole dominant, often forming almost pure stands. Less common grasses include Koeleria cristata and Poa secunda, while Phlox hoodii is an important forb. Stipa comata and Bouteloua gracilis are rare or lacking. Gutierrezia sarothrae is common.

The Bouteloua - Agropyron subtype occurs on clay loam "burn-outs" and has Bouteloua gracilis as the dominant. The droughty nature of the soils caused by impermeability and location in a drier zone favors Bouteloua gracilis while the fine texture favors species of Agropyron, especially in eroded sites. Artemisia cana is less common, and Opuntia polyacantha is prominent. Only four grasses are abundant in the community: Stipa comata,

Koeleria cristata, Poa secunda, and Calamagrostis montanensis.

Quinnild and Cosby (1958) studied the vegetation on two ungrazed mesas in an area known as the Little Missouri River Badlands in western North Dakota. The soils were a silt loam. The plant communities were classified as an Agropyron smithii type, and included the following species listed in order of abundance: Bouteloua gracilis, Agropyron smithii, Stipa viridula, Stipa comata, Artemisia frigida and Agropyron dasystachyum. Bouteloua gracilis was present in an understory topped by the mid-grasses. It seems able to survive in these conditions, and will increase when conditions become less favorable for the mid grasses. Artemisia frigida was the most important forb.

Ecological Relationships of Individual Plant Species

Each plant species responds differently to the environment in which it grows. A knowledge of the response of a species to its exterior environment -- grazing, available soil moisture, soil type, etc. -- will allow the range manager to use that species as an indicator of the environmental conditions on a site. The following literature review summarizes the ecological relationships of the major plant species on the plains of eastern Montana.

Bouteloua gracilis. Grazing research at Manyberries, Alberta, has shown that Bouteloua gracilis dominates heavily grazed sites on loam to clay loam soils in the Mixed Prairie (Dormaar et al. 1977, Smoliak 1974). The large increase in basal area of Bouteloua gracilis was interpreted as an indication of range deterioration. Smoliak et al. (1972) reported that Bouteloua gracilis basal area increased directly with increased grazing pressure by sheep.

In a region where drought is a common occurrence, *Bouteloua gracilis* is reported to be more drought-resistant than the other dominants. It is adapted to sites where water infiltration is restricted, thus leading to a more xeric condition (Coupland 1950). The effect of heavy grazing is to cause a shift in the vegetative community to a composition more adapted to xeric conditions brought about by soil compaction and the lowering of vegetative cover (Coupland 1961).

The production of *Bouteloua gracilis* is dependent upon the moisture which accumulates during May and June; thus, its production fluctuates much more than other grasses such as *Stipa comata* which depend on winter moisture (Morris 1955). Ellison and Woolfolk (1937) found that *Bouteloua gracilis* clumps were reduced in size during a drought. This species is generally considered a warm season grass and is near the northern end of its range in Montana.

Stipa comata. Grazing research indicates that *Stipa comata* declines under heavy grazing (Smoliak 1974, Dormaar et al. 1977, Smoliak et al. 1972). Because of the habit of reproducing from seeds, *Stipa comata* often disappears more rapidly as a result of overgrazing than do species of *Agropyron* and *Bouteloua* (Coupland 1950). However, the numerous seeds produced by *Stipa comata* allow it to rapidly increase on a site when growing conditions become favorable. Of the important grasses, *Stipa comata* seems best able to recover from a drought. Many of the old plants die, but are replaced by numerous seedlings (Ellison and Woolfolk 1937).

Agropyron smithii. Heavy grazing appears to reduce *Agropyron smithii* in the Mixed Prairie type (Smoliak 1974, Coupland 1961, Smoliak et al. 1972). Ellison and Woolfolk (1937) also found that *Agropyron smithii* disappeared from some sites during a drought in eastern Montana.

Coupland (1950) described the ecology of Agropyron smithii. It is a sod-forming grass with long, creeping rhizomes which allow it to spread vegetatively. Under favorable moisture conditions the roots may extend to 8 feet or more in depth. Under dry conditions the portion of the root system absorbing in the surface soil is especially well developed. This species is found on drier soils, and is adapted to gumbo flats, where soil moisture supply is moderate. In contrast to the findings of Ellison and Woolfolk (1937), Coupland reports that Agropyron smithii is hardy and somewhat drought-resistant. It can spread rapidly.

Koeleria cristata. It is most abundant in areas where moisture conditions are favorable. This species is not highly drought-resistant. However, it reseeds a disturbed site easily, and growth which begins in early spring when soil moisture is high favors this species (Coupland 1950). Koeleria cristata increases temporarily when the spring moisture supply is in excess of that required for spring growth by the dominants (Coupland 1961). Heavy grazing generally leads to an increase of this species (Smoliak 1974).

Stipa viridula. This species occurs on the more favorable sites where soil moisture is adequate. Therefore, its distribution is more limited than most of the other grasses (Coupland 1950).

Poa secunda. It occurs most frequently on sandy soils. Growth begins very early in the spring, and is often completed by the time grazing begins (Coupland 1950). Smoliak (1974) found this species to increase with heavy sheep grazing. The early growth habit may explain why Poa secunda generally increases with excess grazing. Ellison and Woolfolk (1937) reported that Poa secunda increased quite noticeably during a drought in

eastern Montana. The increase was brought about not only by the expansion of established plants, but also by the establishment of many seedlings. They attributed its success during a drought to its growth in the fall and early spring when soils moisture is higher.

Artemisia frigida. This species is the most common forb of the Mixed Prairie. It is not readily eaten except during fall and winter. Artemisia frigida increases with overgrazing (Coupland 1950; Sarvis 1923, 1941).

Opuntia polyacantha. This species has been shown to be an indicator of poor range condition on the plains of Kansas and Colorado (Turner and Costello 1960). Reed and Peterson (1961) found a gradual increase in Opuntia polyacantha following heavy grazing in the northern Great Plains. Houston (1963) found that this species increased as a result of a lack of competition by other perennial species adversely affected by dry weather and perhaps a low population of insects. Bement (1968) studied the relationship of Opuntia polyacantha to grazing intensity and Bouteloua gracilis yield on the central Great Plains. He concluded that stocking rate did not affect the abundance of Opuntia polyacantha, nor did control of this species result in an increase in Bouteloua gracilis. From these studies it appears that grazing intensity does not influence the density of Opuntia polyacantha in the northern Great Plains.

Grazing Systems

A grazing system is a plan for manipulating livestock grazing to accomplish a desired result (Range Term Glossary Committee 1964). Fulcher (1973) stated that a major objective of grazing systems in public land management is to maintain or improve range condition. Various terms have been used to describe grazing systems. Only four of these systems

were encountered in our study, so we will confine our discussion to these.

Deferred-rotation grazing is a systematic rotation of deferment on two or more pastures so that each pasture is successively deferred during a different period of the grazing season (Johnston et al. 1975).

Season-long grazing refers to grazing a single range unit throughout the entire growing season (Jeffries 1970).

In rest-rotation grazing, part of the range is grazed while other parts are left ungrazed for part of, or all of, the growing season (Johnston et al. 1975).

Seasonal grazing refers to the use of a range unit on a seasonal basis. Seasonal ranges are those grazed only a part of the growing season, and generally are classified as follows: spring, summer, fall, winter, or spring/fall.

Jeffries (1970) stated that there is no one grazing system which is best under all conditions. He suggested that season-long grazing in Montana is least harmful to ranges dominated by Bouteloua gracilis, Buchloe dactyloides and Poa pratensis. However, bunchgrasses such as Stipa viridula and Agropyron spicatum depend upon seeds for reproduction and are easily damaged unless periodic rests are provided. With proper stocking rates, he suggested that range condition can be maintained but not improved.

Sarvis (1941) found no advantage of deferred-rotation grazing over season-long grazing in North Dakota when proper use was practiced in each system. He stated that the real value of a deferred-rotation system is in restoring an overgrazed area to a normal grazing capacity.

A grazing experiment involving season-long grazing and deferred-rotation grazing was conducted at the Northern Great Plains Field Station

at Mandan, North Dakota (Rogler 1951). The dominant species were *Bouteloua gracilis*, *Agropyron smithii*, *Carex filifolia* and *Stipa comata*. When a heavy stocking rate was used for both grazing systems, the season-long grazing caused a decline in the desirable species, while the deferred-rotation system maintained the desirables.

Hubbard (1951) conducted a grazing study at the Dominion Range Experiment Station, Manyberries, Alberta, to compare season-long grazing to deferred-rotation grazing on short-grass prairie. Both *Bouteloua gracilis* and *Stipa comata* decreased under heavy grazing using both grazing systems, *Agropyron smithii* did equally well under both systems, and *Poa secunda* increased. The main forage species, including *Bouteloua gracilis*, *Stipa comata*, *Koeleria cristata* and *Agropyron smithii* did better under the deferred-rotation system.

Smoliak (1960) studied the influence of season-long grazing and deferred-rotation grazing on shortgrass prairie in Alberta. One pasture was grazed continuously for six months each year. An adjacent pasture was divided into two pastures and each was grazed for one and one-half months in the spring and again in the fall on alternate years, and for three months in the summer during years when no spring/fall grazing was scheduled. There was no difference in total ground cover of *Bouteloua gracilis*, *Stipa comata*, *Koeleria cristata* or *Agropyron smithii* between the two systems. The forage in the season-long pasture was significantly higher in protein five years out of six.

Campbell et al. (1962) found that a pasture grazed season-long produced as much or more beef as one divided into two or three units and grazed in rotation at the same rate. The grass cover on the Canadian prairie was usually greater when the pastures were rotated, allowing

the plants to produce seeds and maintain food reserves.

Jefferies (1970) stated that a deferred-rotation system aids in increasing utilization on sites not normally grazed under season-long grazing. He said that forage production usually increases rapidly on low condition bunchgrass ranges under a deferred-rotation system, but is slower on Bouteloua gracilis ranges or those in high condition. This system was said to not be well-adapted to ranges having large variations in vegetation or topography.

Rotation grazing consists of shifting livestock systematically at desirable intervals to different subunits of a range area or fenced subdivisions, and back to the first subdivision, without specific provision for seed production (Sampson 1951). The stated objectives are 1) to avoid grazing the same subunit first each spring, and 2) to maintain the plant cover over the entire range in a high state of vigor with little or no decrease in animal production. However, Johnston et al. (1975) reported that daily gains by livestock are frequently lower under rotational grazing than season-long grazing. Herbel (1971) wrote that most studies show that livestock production per animal is the same or lower for a rotation system compared to a season-long system. Perhaps the higher gains of livestock on ranges grazed season-long is that they have access to all the plants in the pasture at the time they are most nutritious (Rogler 1951).

The rest-rotation system was established on mountain bunchgrass ranges in northeastern California that had been overgrazed by livestock (Hormay and Talbot 1961). Hormay (1970) listed the purposes of rest-rotation grazing as follows: 1) to allow plants an opportunity to make and store food -- to recover vigor, 2) to allow seed to ripen, 3) to allow seedlings to become established, and 4) to allow litter to accumulate between plants.

Eckert (n.d.) evaluated the use of rest-rotation grazing in Nevada. He stated that rest-rotation grazing will probably not work on a range having palatable grasses and unpalatable shrubs such as *Artemisia tridentata*, because the shrubs gain a competitive advantage each year a range is grazed. The rest-rotation system will more or less improve vigor of desirable forage plants and maintain the existing range condition on Nevada grass/shrub ranges (Eckert n.d.).

Ross (1973) is more optimistic about use of rest-rotation grazing to improve Montana ranges. He stated that from the standpoint of grass management, a rest rotation system is the quickest system for improving ranges, provided that grazing is not excessive. Jefferies (1970) wrote that rest-rotation grazing works well on bunchgrass ranges in poor to fair condition in Montana. Such ranges depend on seed production for regeneration. However, he cautioned that range improvement on the plains of Montana is much less reliable, and that rest-rotation grazing is not easily applied to areas of dissimilar vegetation and topography.

A review of research related to grazing systems has been made by Herbel (1971). He stated that in areas with short growing seasons, it appears that any deferment period on ranges grazed only for part of a year should be brief, and should coincide with a critical period of growth. A system allowing deferment on one unit during the spring will be favorable to that unit, but there is a question about whether the placing of excess numbers of animals on the other grazing units during the spring may not offset the benefits gained through deferment of the one unit (Herbel 1971).

Lodge (1970) concluded that for the northern Great Plains where grazing is based on the exclusive use of natural grassland, no system of grazing is better than season-long grazing. However, Wambolt (1973)

suggested that a grazing system such as rest-rotation or deferred-rotation may help to obtain a more even distribution of grazing by concentrating a larger number of animals in a pasture for a short time. This forces them to eat plants that might otherwise be ungrazed. The animals may also be forced into areas that they might not otherwise graze to any extent.

This review of literature related to grazing systems illustrates the attempt of researchers and managers to develop a better system for grazing native ranges than the standard practice of grazing a range annually for the entire growing season. It is obvious that there is no consensus of opinion about the best system to use, or about the results that can be expected from the use of any system. However, it appears that ranges dominated by plants that reproduce mostly vegetatively (*Bouteloua gracilis*, *Agropyron smithii*, and *Buchloe dactyloides*) might not respond to periods of rest or deferment nearly as rapidly as ranges dominated by plants that reproduce only by seeds (*Stipa comata*, *Agropyron spicatum*, *Stipa viridula*).

Effects of Grazing on Soil Moisture

Stoddart et al. (1975) stated that grazing animals tend to compact a soil, often to surprising depths, especially when the soil is wet. These compacted soils are poor absorbers of precipitation. Even though soil compaction by grazing animals has repeatedly been demonstrated, this does not occur in all conditions. Smoliak et al. (1972) showed that increased stocking rates of sheep on loam and clay loam, *Stipa* - *Bouteloua* prairie soils had little effect on soil physical properties such as compaction. The soils were generally dry when grazing occurred.

Grazing may alter the natural infiltration - runoff relationships by

compaction through trampling (Stoddart et al. 1975). Soil structure can be altered considerably by trampling, as illustrated by Flory (1936). Soils on ungrazed, overgrazed and severely grazed range sites in New Mexico had pore space of 68.1, 51.1, and 46.5 percent, respectively.

RESULTS

Twenty-seven sites were sampled in eleven grazing allotments. Locations of sites are shown on allotment maps in Figures 1 through 8. Considerable variation exists in the soils, potential vegetation, and topographic position among plots; therefore, the plots have been grouped by range site for comparisons.

A range site is an area of land having a combination of edaphic, climatic, topographic and natural biotic factors that is significantly different from adjacent areas (Range Term Glossary Committee 1964). Dyksterhuis (1949) provided a more complete definition of a range site as follows:

> Range sites are embodied with those areas where the soils and climatic environment sustain natural grass, forb, and shrub communities. Variation in soil (texture, depth, and permeability) and climate (precipitation, elevation, temperature, and exposure)determine measurable and important differences in the kind and/or amount of the climax vegetation. Each specific complex of soil and climatic conditions is called a range site.

Site is not to be confused with type, because many types of vegetation may successively occupy the same range site in response to different grazing treatments (Dyksterhuis 1958). Thus, a range site provides information about the potential vegetation of an area, while a range type describes the existing vegetation, particularly the dominants.

Range condition has been defined as the percentage of the present

vegetation which would be present in the climax for the site. Thus, the condition can be expressed numerically as a percentage, and can also be expressed in terms of condition class: excellent (76-100%), good (51-75%), fair (26-50%), and poor (0-25%).

Dense Clay Range Site

The dense clay range site includes relatively impervious deep, non-granular clays which may be overlain by thin ineffectual layers of other materials. The dispersed layer is very hard to extremely hard when dry, and very sticky when wet (Ross and Hunter 1976).

Four sample sites were on a dense clay range site: sites 1 and 3 (Lewis Reservoir), site 4 (Miller Coulee) and site 13 (Bullwacker). Each of these allotments has been grazed by a 5-pasture rest-rotation system. Sites 1, 3, and 4 are in the Eastern Sedimentary Plains, while site 13 is in the Western Sedimentary Plains.

Site No. 1. This site involved a comparison of a 5-pasture rest-rotation system (established 10 years) to season-long grazing (Table 1). Total plant production was higher in the pasture grazed season-long, mostly because of a much higher amount of *Opuntia polycantha*. The pasture grazed by a rest-rotation system has a greater production of desirable grasses, mostly *Poa secunda*, and better range condition. *Atriplex nuttallii* contributed approximately one-half of the total production on each site, and there was no difference in vigor between pastures. Vigor of *Poa secunda* was higher in the rest-rotation pasture. There was essentially no difference in the amount of litter in each pasture, but the water infiltration rate was higher in the rest-rotation pasture.

Site No. 3. This site provided a comparison between a 5-pasture rest-

rotation system (established 10 years) and a 3-pasture rest-rotation system (established only 3 years). The 5-pasture rest-rotation unit contained considerably more total plant production, mostly due to a heavy infestation of Opuntia polycantha. The 5-pasture system had more pounds of desirable grasses, Atriplex nuttallii, and litter, but the site examined was in poor condition, while the site in the 3-pasture unit was in fair condition. Soil water infiltration was slightly higher in the 3-pasture unit. It is interesting to note that even through the 5-pasture rest-rotation system had been established for 10 years, the range was still in poor condition.

Site No. 4. This site is a comparison of a 5-pasture rest-rotation system (established 4 years) and a 4-pasture rest-rotation system (established 4 years). These two systems have not been established for a sufficient period of time for the soils and vegetation to respond to treatment. However, the past use on the 4-pasture unit has resulted in more total production, more Atriplex nuttallii and Opuntia polycantha, a better range condition, and better vigor of A. nuttallii (Table 1). Litter was much higher on the 5-pasture unit, and infiltration rates were also higher. These two units should be compared again after several years to determine whether these differences will continue to exist.

Site No. 13. This site compares a 5-pasture rest-rotation system (established 9 years) to season-long grazing (Table 1). Since this site is in the Eastern Glaciated Plains, it can not necessarily be compared to sites 1, 3, and 4 which are in the Eastern Sedimentary Plains. One of the major observed differences between the plant communities is a dominance of Atriplex nuttallii on sites 1, 3, and 4, and a dominance of Artemisia tridentata on site 13.

The pasture grazed by a 5-pasture rest-rotation system contained more desirable grasses, less Opuntia polycantha, much more litter, and was in better range condition. The vigor of Agropyron smithii was significantly higher and soil water infiltration was more rapid than in the unit grazed season-long.

Shallow Clay Range Site

The shallow clay range site has shallow granular clay soils that are 10 to 20 inches deep to underlying shale or nearly impervious clays (Ross and Hunter 1976).

Four sites were sampled on a shallow clay range site: site 2 (Lewis Reservoir), site 8 (Lavelle Creek), site 14 (Bullwacker) and site 15 (Bull-wacker and Hay Coulee). Site 2 is in the Eastern Sedimentary Plains, while the other three sites are in the Western Sedimentary Plains.

Site No. 2. This site was selected to compare the effects of a 5-pasture rest-rotation system (established 10 years) to season-long grazing. A superficial review of the data leads one to assume that the vegetation is responding better to season-long grazing. The pasture grazed under a rest-rotation system has lower total production, fewer desirable grasses, more Artemisia tridentata, more Opuntia polycantha, and a lower range condition (Table 2). However, the vigor of the key species, Agropyron smithii, is significantly higher, plant litter is greater, and soil water infiltration rates are higher in the rest-rotation pasture. It seems, then, that the rest-rotation system is more conducive to range improvement than the season-long grazing. It appears that in time, if the present grazing practices are continued, the rest-rotation pastures will be in better condition than the pasture grazed season-long.

Site No. 8. This site compares a 4-pasture rest-rotation system to season-long grazing. Differences in the soils and vegetation between the two sampled pastures are only slight. The rest-rotation pasture has more total production, but much of this is comprised of Artemisia tridentata. Total grass production is slightly higher, and there is less Opuntia polycantha in the rest-rotation pasture, but range condition is also lower (Table 2). There is no significant difference in vigor of Agropyron smithii, the key species. Infiltration rates for the first five minutes are slightly higher in the pasture grazed season-long, but the rate for fifteen minutes is slightly higher in the rest-rotation pasture.

Site No. 14. This site compares a 5-pasture rest-rotation system (established 9 years) to an exclosure which has been in existance for many years. The exclosure had more total herbage production, more Agropyron smithii, somewhat more Atriplex nuttallii, essentially the same amount of Artemisia tridentata, more litter, and significantly higher vigor of Atriplex nuttallii (Table 2). However, there was no difference in the vigor of Agropyron smithii, the key species. The range condition was fair on both areas, and was low because of the large percentage of Artemisia tridentata present. It is also interesting to note that the infiltration rates were consistantly higher on the grazed site, although the reason is not readily apparent.

Site No. 15. On this site a pasture grazed under a 5-pasture rest-rotation system for 9 years is compared to a pasture grazed in the winter. Generally, the winter-grazed pasture appears to be in better condition. More Agropyron smithii is present than in the rest-rotation pasture, but there is no difference in its vigor (Table 2). Considerable less Artemisia tridentata is present in the winter-grazed pasture, the range condition is

higher, much more litter is present, and infiltration rates are higher.

Clayey Range Site

The clayey range site includes soils which are a granular clay loam, silty clay loam, silty clay, sandy clay, or clay more than 20 inches deep (Ross and Hunter 1976).

Eleven sample sites were on a clayey range site: sites 6 and 7 (Lavelle Creek), sites 10 and 11 (Rock Creek), site 9 (Lavelle Creek/Rock Creek), sites 17 and 22 (King), sites 19, 20, and 21 (Iverson), and site 27 (Burgess). All of these sites are in the Eastern Sedimentary Plains.

Site No. 6. This site compares a pasture which had been grazed 12 years under a 4-pasture rest-rotation system to an ungrazed site (a protected site in the highway right-of-way). The protected site had not been mowed or burned, as evidenced by undisturbed *Artemisia tridentata* plants. The ungrazed site was generally in better condition. Significantly more desirable grasses, especially *Agropyron smithii*, were found on the ungrazed site, there was somewhat less *Artemisia tridentata*, range condition was higher, much more litter was present, and the vigor of *Atriplex nuttallii* was higher (Table 3). However, the vigor of *Agropyron smithii* did not differ significantly between the grazed and protected areas. The infiltration rates were relatively low on both areas, and were somewhat higher in the grazed pasture.

Site No. 7. This site was selected to compare a pasture which had been grazed 12 years under a 4-pasture rest-rotation system to an ungrazed site. The ungrazed site is in a highway right-of-way which had not been disturbed by mowing, burning or grazing. Soil and vegetation conditions are generally

better on the protected site. Total forage production is higher, more desirable grasses are being produced, range condition is higher, the vigor of *Agropyron smithii* is significantly better, litter is more abundant, and soil infiltration rates are higher (Table 3). These data indicate that 12 years of grazing under the rest-rotation system have not been sufficient to improve the range to its potential.

Site No. 9. This site compares season-long grazing to a pasture grazed 12 years by a 4-pasture rest-rotation system. Both of these areas were found to be in poor condition. The rest-rotation pasture had slightly more total production, much more *Opuntia polycantha*, slightly more litter, and somewhat higher soil infiltration rates. This site apparetnly responds very slowly to improvement under a rest-rotation system.

Site No. 27. This site includes a 6-pasture rest-rotation system in operation for 9 years compared to a pasture grazed yearlong. The range condition was higher on the rest-rotation area, mostly because of a greater amount of *Agropyron smithii*. Total production, *Opuntia polycantha* and *Bouteloua gracilis* were essentially the same for both areas (Table 3). However, the vigor of *Agropyron smithii* was significantly better on the pasture grazed yearlong, litter was much higher, and infiltration rates were higher.

Site No. 17. This site compares a pasture grazed for 8 years under a 5-pasture rest-rotation system and a pasture grazed annually from June to September. The pasture grazed under a rest-rotation system was in a higher range condition, had more total production, much more *Agropyron spicatum*, more *Agropyron smithii* and *Koeleria cirstata*, more litter, and higher infiltration rates (Table 4).

Site No. 19. A 3-pasture rest-rotation system in operation for 8 years is compared to a pasture grazed annually from April to September. Total production and litter were higher in the pasture grazed from April to September and the production of Opuntia polycantha was much higher (Table 4). However, the rest-rotation pasture was in better range condition, the production of desirable grasses was higher, the vigor of Stipa viridula was significantly higher, and infiltration rates were much higher.

Site No. 20. This site was selected to compare a pasture grazed for 8 years under a 3-pasture rest-rotation system to a pasture grazed annually from May to October. Total production, production of Opuntia polycantha and Agropyron smithii, and litter were higher on the pasture grazed annually from May to October (Table 4). However the rest-rotation pasture was in much better condition, had more production of desirable grasses, the vigor of Agropyron smithii was significantly higher, and infiltration rates were very much higher. An interesting difference between the two pastures was the presence of significant amounts of Stipa viridula in the rest-rotation pasture, while none was present on the area grazed annually from May to October.

Site No. 21. This site compares a 3-pasture rest-rotation system established 8 years to a pasture grazed continually from May to October. All measurements taken on both pastures indicate that the vegetation and soils are better on the rest-rotation pasture (Table 4). Total production is higher, the vigor of Agropyron smithii is significantly higher, more litter is present, and infiltration rates are higher in the rest-rotation pasture. Agropyron spicatum and Koeleria cristata are only present in the rest-rotation area, and significant amounts of Stipa viridula are only found in the same pasture.

Site No. 10. This site compares a pasture grazed seasonlong to one grazed from fall to the following spring. Total production on both areas is very low, and there is not much difference in the plant composition on both areas (Table 5). More total production and litter are present in the pasture grazed seasonlong, but the infiltration rates are very similar. The major difference in the vegetation is in the vigor of the key species. Vigor of Agropyron smithii and Bouteloua gracilis was significantly higher in the pasture grazed form fall to spring each year.

Site No. 11. This site was selected to compare a pasture grazed seasonlong to one grazed from April to June annually. Both pastures have about the same total production, but the pasture grazed April to June has more Agropyron smithii, and its vigor is significantly better in this pasture (Table 5). Artemisia tridentata comprises from 55 - 70% of the total production in the pastures. Range condition is slightly better in the pasture grazed April to June, but neither range is in very good shape. Litter is about the same in both pastures, but the infiltration rate is somewhat higher in the seasonlong pasture. Neither of these systems of grazing seems conducive to providing for range improvement.

Site No. 22. This site compares a 5-pasture rest-rotation system established 8 years to a pasture grazed annually from June to September. The rest-rotation pasture has more total production, much more production of Agropyron spicatum, better range condition, significantly higher vigor (measured as number of seedstalks/plant), and much higher soil infiltration rates (Table 5). Litter production is higher in the pasture grazed June to September, but much of this is derived from Artemisia tridentata.

Silty Range Site

The silty range site includes soils more than 20 inches deep of very fine sandy loam, loam, or silt loam. This includes soils with two inches or more or loam or silt loam over clayey subsoils (Ross and Hunter 1976).

Seven sample sites were on a silty range site: sites 23 and 24 (Snell), sites 25 and 26 (Burgess), site 12 (Hay Coulee), and sites 16 and 18 (King). Site 12 is in the Western Sedimentary Plains, and the rest are in the Eastern Sedimentary Plains.

Site No. 23. This site compares a 2-pasture deferred-rotation system established for 6 years to a pasture grazed annually in the winter. Total production, production of *Stipa comata* and *Bouteloua gracilis*, and litter are greater on the winter-grazed pasture (Table 6). However, *Agropyron smithii* production and range condition are similar on both areas sampled. Vigor of *Stipa comata* is significantly higher on the deferred-rotation pasture, but there is no difference in the vigor of *Bouteloua gracilis*. Infiltration rates are similar on both pastures.

Site No. 24. This site provides a comparison of a 2-pasture deferred-rotation system (established for 6 years) and a pasture grazed annually from May to October. Total production and litter are higher on the pasture grazed annually from May to October (Table 6). Range condition and production of desirable grasses are similar on the two areas sampled. Vigor of *Stipa comata* is higher in the deferred-rotation pasture, but there was no difference in *Agropyron smithii* vigor. *Stipa comata* was more productive in the deferred-rotation pasture, *Agropyron smithii* and *Koleria cristata* were somewhat lower, while *Bouteloua gracilis* was about the same. Soil water infiltration rates were slightly higher in the

deferred-rotation pasture. The grazing system probably has not been in effect long enough to effect significant changes in the soils and vegetation.

Site No. 25. This site compares a 6-pasture rest-rotation system to a pasture grazed yearlong. The pasture grazed yearlong had more total production, much of which was contributed by Opuntia polycantha. Infiltration rates were also higher, but it was in poor condition (Table 6). Conversely, the rest-rotation pasture was in good condition, had more Stipa comata and Agropyron smithii, more production of desirable grasses, and significantly better vigor of Stipa comata. Amounts of litter were similar on both pastures.

Site No. 26. This site was selected to provide a comparison of a 6-pasture rest-rotation system established 9 years and a pasture grazed annually in the winter. Total production, range condition, and infiltration rates were similar on both sample areas (Table 6). The rest-rotation pasture had more production of Stipa comata, and its vigor was significantly higher. The winter-use pasture had more Opuntia polycantha and much more litter.

Site No. 12. This site compares a pasture grazed in the fall to one grazed seasonlong. Fall grazing definitely appears to be better than seasonlong grazing on this site. The pasture grazed in the fall has much more total producion; more production and significantly better vigor of Agropyron smithii and Bouteloua gracilis; and better soil infiltration rates (Table 7). Range condition and litter are similar on the two pastures.

Site No. 16. A 5-pasture rest-rotation system established for 8 years is compared to a pasture grazed August to November each year. The

pasture grazed by the rest-rotation system had more production of desirable grasses, significantly better vigor and more production of Calamagrostis montanensis, and higher soil infiltration rates (Table 7). However, this pasture at the location of our sampling was in poor condition. The pasture grazed August to November had more total production, mostly because of a higher production of Artemisia tridentata; litter was much higher; Agropyron smithii production was higher; and the pasture was in fair condition.

Site No. 18. A pasture grazed during the winter (December-April) was compared to a 5-pasture rest-rotation system established 8 years. Conditions in the winter-grazed pasture are generally somewhat better than in the pasture grazed under a rest-rotation system (Table 7). Production of desirable grasses is higher, range condition is better (although both pastures are in fair condition), litter on the soil surface is much higher, and Koeleria cristata vigor is significantly better. The rest-rotation pasture has more total production, but this is a result of the greater production of Artemisia tridentata present. Vigor of Agropyron smithii is significantly higher in the rest-rotation pasture. Soil water infiltration rates are similar in both pastures.

Saline Upland Range Site

The saline upland range site includes upland soils more than 20 inches deep with salt and/or alkali accumulations. Salt tolerant plants occur over a major part of the area (Ross and Hunter 1976).

Only one site was located on a saline upland range site: site 5 Miller Coulee/Lower Little Beaver). This site is located in the Eastern Sedimentary Plains.

Site No. 5. This site compares a 4-pasture rest-rotation system (established for 4 years) to a 3-pasture rest-rotation system (established for 3 years). Neither system has been established long enough to provide a comparison between systems. However, these data can serve as a basis for detecting changes at some future date after the soils and vegetation have had time to respond to the grazing system. Present total production is very low in both areas sampled at the site, but there is little difference between pastures. Production of desirable grasses is very low and litter is very sparse in both areas. However, conditions appear to be somewhat better in the 4-pasture rest-rotation treatment: range condition is higher, *Atriplex nuttallii* production is higher, the vigor of *Agropyron smithii* is significantly higher, and soil water infiltration rates are considerably higher (Table 7).

DISCUSSION AND CONCLUSIONS

The use of fence-line contrasts to assess the impacts of various grazing regimes has certain advantages. It allows for a comparison at one point in time of past influences of two different grazing treatments. Also, the impacts of a particular grazing system can be contrasted to a non-grazed site to determine how the vegetation and soil conditions in the grazed site compare to the potential.

A comparison can be made only if the difference between the conditions on each side of the fence is related entirely to past grazing. Soils, potential vegetation, slope, aspect, and approximate distance from water must be the same. Also, a direct comparison can be made only if the past grazing history is known.

Range trend is best determined when baseline data relative to conditions several years prior to the study are available. Determination of range trend at one point in time must rely on indicators of trend. Vigor of key forage species and soil water infiltration rates (an indication of soil compaction) have been used as indicators of trend in our study. It is assumed that if plant vigor and infiltration rates are higher in one pasture than in another, then the grazing regime in the first pasture will be more conducive to range improvement.

Range condition relates the seral stage of the plant community at one point in time to the potential. It provides no indication of range trend (whether the range is improving or deteriorating). Thus, a range in good condition may be deteriorating, while one in fair condition may be improving; e.g., a better range condition does not imply that the grazing regime in that pasture is more conducive to range improvement.

Range improvement is dependent on the succession of plant species on the site, such that the species in higher successional stages replace those in lower stages. The presence of long-lived perennials, especially *Artemisia tridentata* and *Opuntia polycantha*, dictate that progressive succession will be very slow. Such long-lived, low-successional species often comprise a significant percentage of the plant community. Since they are found in a very small percentage in the climax plant community, their presence will automatically depress the range condition. Range condition on such sites will improve slowly, regardless of the grazing regime, until these plants eventually die, to be replaced by plants common to higher seral stages. Thus, it is important to consider all factors which indicate range improvement: range condition, vigor of

key forage species, litter accumulation, and soil water infiltration rates (soil compaction).

Soil compaction is a very important influence of grazing to be considered in judging range trend. A compacted soil with minimal amounts of surface litter will be a more xeric soil because more precipitation will be lost by runoff rather than penetrate into the soil. Thus, a drier site will have less total plant production and will support more xeric plant species which are found in lower seral stages.

Artemisia tridentata can also lead to a more xeric condition. A dense canopy of the species catches snow before it reaches the ground. The foliage is dark and acts as a block-body radiator. Thus, some of the snow evaporates without ever reaching the ground. The retention of snow on the canopy provides for more bare ground beneath the shrubs. Since bare ground freezes deeper in winter, more runoff occurs as snow melts. Thus, the evaporation, transpiration, and surface runoff contributed by *Artemisia tridentata* leads to a more xeric site.

To truly assess the impacts of a grazing regime, both the grazing schedule and degree of use (light, moderate, excessive) should be considered. A review of the allotment management plans on which our study sites were located indicates that proper use was generally applied to the established grazing systems. Thus, we have assumed proper use in these pastures. A determination of the degree of use in privately owned pastures is much more difficult, as ranchers are reluctant to admit overgrazing a range. In some cases, the degree of past use on private land was not completely established. However, reference to a grazing regime, and its impacts, will infer the impact of the grazing schedule and degree of use.

Several types of information can be obtained with a fence-line contrast study. This allows a comparison of one grazing regime to another. Also, the existing range condition can provide valuable information on a range where a grazing system has been established for several years. If the range is in poor condition, this indicates the slowness of the site to improve under such a grazing system. However, if a range is in fair to good condition, there is no evidence about whether the condition has changed after the system was established. Vigor of key plant species and soil water infiltration rates appear to be the best indicators of whether a grazing regime is satisfactory.

A few of the sites which we sampled have had a grazing system established for three or four years. This is not sufficient time for the soils and vegetation to adequately respond to the system. Therefore, few if any conclusions can be drawn on these sites at this time. Our data can be used as baseline data for future comparisons.

Even though certain limitations to use of the fence-line contrast method were encountered, we were able to draw several observations and conclusions from our data. The following discussions summarize the influence of various grazing regimes which we found in our study. Grazing systems established for less than six years will not be used for drawing conclusions.

Soil Infiltration Rates

Nine sample sites compared a five-pasture rest-rotation system to an exclosure, and to summer, fall, winter, and seasonlong grazing. Soil water infiltration rates were higher in the rest-rotation pastures on

seven sites. Only on two sites grazed during winter were infiltration rates higher or similar to those on five-pasture rest-rotation sites.

Four sites involved a comparison of four-pasture rest-rotation to seasonlong grazing and no grazing. Infiltration rates were higher on the four-pasture rest-rotation areas than on two comparable areas grazed seasonlong and one non-grazed site. Another non-grazed site had higher rates.

Infiltration rates in pastures grazed by a three-pasture rest-rotation system were higher than pastures grazed seasonlong, or spring-summer. However, on three sites where a six-pasture rest-rotation system had been in operation for nine years, rates were lower than in comparable pastures grazed yearlong and in winter. Reasons for these lower infiltration rates for a six-pasture system are not readily apparent. However, it is possible that at least two full cycles (12 years) or more would be necessary before any appreciable improvement of compacted soils may occur.

Seasonlong grazing appears to compact soils more than fall grazing or late fall to early spring use. However, spring grazing caused soil compaction more than seasonlong grazing.

Infiltration rates in pastures grazed by a two-pasture deferred-rotation system were higher than those in a pasture grazed seasonlong, but lower than one grazed only during the winter.

In general, soil water infiltration rates were higher in pastures grazed during the winter, followed closely by range allotments grazed by a rest-rotation system (three-pasture, four-pasture, or five-pasture) and a two-pasture deferred-rotation system. Spring grazing appears to result in the greatest soil compaction and lowest infiltration rates.

Vigor of Key Species

Grasses which Reproduce by Seeds. Our data indicate that the vigor of the major grass species which reproduce by seeds is favored by rest-rotation and deferred-rotation grazing over almost any other grazing regime tested. This maintenance of higher vigor would serve to maintain these species in the stand. *Agropyron spicatum* vigor was much better under a five-pasture rest-rotation system than when grazed during the summer. Vigor of *Stipa viridula* was much higher in a three-pasture rest-rotation system than in a pasture grazed during spring and summer.

Vigor of *Poa secunda* was significantly higher in a five-pasture rest-rotation system than in a pasture grazed seasonlong. This species greens up very early in the spring, so that it is often the first green grass available. Thus, seasonlong grazing would apply continual pressure when *Poa secunda* is most vulnerable.

Winter grazing of a pasture containing *Koeleria cristata* resulted in higher vigor than a five-pasture rest-rotation system. *Koeleria cristata* would often be covered by snow during winter, and would be grazed very little, if any, under winter grazing.

Stipa comata was favored by two-pasture deferred-rotation and six-pasture rest-rotation grazing over winter, seasonlong, and yearlong grazing on four separate sample sites.

Grasses Which Reproduce Vegetatively. Vigor of *Agropyron smithii* was significantly lower in pastures grazed seasonlong when compared to a five-pasture rest-rotation system, a three-pasture rest-rotation system, spring grazing, fall grazing, and fall-spring grazing. On other sample sites, no differences in vigor were detected between rest-rotation

grazing and seasonlong, winter, or ungrazed pastures. On one site, a pasture grazed yearlong had Agropyron smithii plants in better vigor than in a six-pasture system across the fence. At another site, vigor of this species was higher under complete deferment than in a four-pasture rest-rotation system; it appears, then, that some form of periodic deferment or rest is needed by Agropyron smithii to maintain vigorous plants.

Grazing of Bouteloua gracilis in the fall, winter, or early spring on two sites provided far more vigorous plants than did seasonlong grazing. This is to be expected, as Bouteloua gracilis is a warm season grass and would be favored by rest or deferment during the warm part of the growing season. However, no differences in vigor were found on three other sites, where the following grazing histories were compared: four-pasture rest-rotation compared to an ungrazed area and a pasture grazed seasonlong, and a two-pasture deferred-rotation system compared to winter grazing.

The vigor of Calamagrostis montanensis was measured on only one site. Vigor was significantly higher under a five-pasture rest-rotation system than under fall grazing. We were unable to determine why the fall grazing caused a reduction in vigor. This species reproduces almost entirely by rhizomes, so that reproduction by seeds in unimportant. It is likely that fall grazing affects carbohydrate storage in the rhizomes, and that the elongation of rhizomes occurs during the fall. Continual fall grazing would keep the plants under stress during the reproductive period.

Vigor of Atriplex nuttallii. No difference in vigor of Atriplex nuttallii was found in a pasture grazed under a five-pasture rest-rotation

system and in one grazed seasonlong. However, vigor was significantly higher on ungrazed sites compared to rest-rotation. It appears that a rest-rotation system is not conducive to high vigor of *Atriplex nuttallii*. However, this species occurs on a very harsh site. It is possible that vigor is improving under rest-rotation, but if this is occurring, improvement is not apparent in the length of time these pastures have been in a rest-rotation system.

Plant Litter

Influence of past grazing practices on the amount of litter present on the ground surface is closely related to the plant species present, productivity of the site, and time of year when grazing occurs. Some sites are very harsh and, regardless of the grazing practices, inherently produce low amounts of litter (10-20 pounds per acre). Other sites, especially those having bunchgrass or *Artemisia tridentata* produce much more litter, with that of the woody shrubs being more persistent. Thus, an adequate amount of litter on one site may be much less than an inadequate amount on another.

Litter on sites grazed under a four-pasture or five-pasture rest-rotation system was generally greater than in a pasture grazed seasonlong or under a three-pasture rest-rotation system. However, ungrazed sites, and those grazed in winter or fall generally had more litter than those grazed under a four-pasture or five-pasture rest-rotation system. Litter accumulation under summer grazing was less predictable: one site grazed during the summer had more litter than on a five-pasture rest-rotation system, while the reverse was true on another site. In general, seasonlong grazing does not allow for much litter accumulation, and litter is allowed to build up more as the season progresses through summer, fall, and winter.

Litter accumulation was higher under yearlong grazing (2 sites) and winter grazing (1 site) than under a six-pasture rest-rotation system. The reason for less litter build-up under a six-pasture system is not readily apparent.

Pastures grazed seasonlong had more litter accumulation than those grazed in spring, fall to spring, a two-pasture deferred-rotation system,

and a three-pasture rest-rotation system; produced about the same amount as a fall-grazed pasture; and produced less litter than a three-pasture rest-rotation system.

A two-pasture deferred-rotation system had less litter than a winter-grazed pasture, whereas a three-pasture rest-rotation system had less litter than a pasture grazed spring and summer.

It appears, then, that a four-pasture rest-rotation system, a five-pasture rest-rotation system, winter grazing, and fall grazing allow for the greatest amount of litter build up.

Range Condition

No direct comparisons of range condition can be made on any site, since the condition present at the time the grazing systems were established is unknown. However, the range condition data do allow the formulation of certain conclusions relative to range improvement under rest-rotation and deferred-rotation grazing. It is obvious that range improvement is very slow under these systems, even after eight to twelve years. For example, in a four-pasture rest-rotation system established for twelve years, two sites were still in poor condition and two were classified as fair. Under a five-pasture rest-rotation system established eight to ten years, two sites were in poor condition and six were fair. Thus, range condition may not be the best criterion for determining the usefulness of rest-rotation grazing for range improvement over a short time.

On several sites, range condition was better under grazing systems normally considered detrimental to the range, such as continuous grazing and spring grazing, than under rest-rotation grazing. It is probable that these sites in rest-rotation systems were in a lower condition when the system was established. Thus, it appears more appropriate to base range

improvement over a short time on vigor of key forage species and soil water infiltration rates.

Occurrence of *Opuntia polycantha*

The influence of past grazing practices on *Opuntia polycantha* was not well established in this study. However, when rest-rotation grazing was compared to seasonlong grazing, the percentage of *Opuntia polycantha* was highest in pastures grazed seasonlong on all sites. This observation is in agreement with other studies (Turner and Costello 1960, Reed and Peterson 1961) that overgrazing leads to an increase in this species. Houston (1963) reported increases in *Opuntia polycantha* because of a lack of competition from other perennial species. Thus, it appears from our study that any grazing scheme which results in over use of the perennial grasses may lead to an increase of *Opuntia polycantha* on the northern Great Plains.

Forage Production

Grazing systems are designed not only to improve range condition but also to increase forage production. Total herbage production is not an indication of forage production, since relatively unpalatable shrubs and herbaceous species are included. We have chosen to express forage production in terms of desirable grass production.

Production of desirable grasses under rest-rotation grazing was higher on almost all sites when compared to seasonlong, fall, summer, and spring/summer grazing. Production was usually higher on ungrazed areas and pastures grazed during winter when compared to rest-rotation pastures.

CONCLUSIONS

The use of rest-rotation grazing in the northern Great Plains has been questioned (Herbel 1971, Lodge 1970). However, our study indicates that rest-rotation grazing in Eastern Montana is generally better than seasonlong grazing. Generally, rest-rotation grazing allowed for better vigor of key forage species, faster soil water infiltration, more litter on the ground surface, reduced amounts of *Opuntia polycantha*, and greater production of desirable grasses for forage. Conversely, seasonlong grazing resulted in lower plant vigor, slower soil water infiltration, less litter, less production of desirable grasses, and more *Opuntia polycantha*.

Of all the grazing regimes included in our study, only winter grazing allowed for better soil and plant conditions than did rest-rotation grazing. However, this is to be expected. Plants are dormant during winter, so that adverse effects of grazing would be minimal. Soils are frozen during this time and would be relatively free from compaction by trampling.

Only two sites grazed under a deferred-rotation system were sampled. The system had been in use for six years, a period which is too short to allow the plants and soil to fully respond. No definite conclusions were drawn about the usefulness of this system.

It is apparent from our study that range improvement in the northern Great Plains is slow. Even though range improvement is occurring on a site, a long period of time is required before substantial improvement in range condition will occur.

Table 1. Vegetation characteristics and soil water infiltration rates on dense clay sites grazed by five-pasture rest-rotation system compared to other past treatments.

Comparison Parameters	Treatment Comparisons							
	Site No. 1		Site No. 3		Site No. 4		Site No. 13	
	5-Pasture Rest-Rotation (10 years)	Season-long Grazing	5-Pasture Rest-Rotation (10 years)	3-Pasture Rest-Rotation (3 years)	5-Pasture Rest-Rotation (3 years)	4-Pasture Rest-Rotation (4 years)	5-Pasture Rest-Rotation (9 years)	Season-long Grazing
Total Production (lb/ac)	405	457	663	305	253	327	187	224
Desirable Grasses (lb/ac)(% of total)	63(16%)	27(6%)	40(6%)	25(8%)	17(7%)	26(9%)	57(30%)	43(19%)
Atriplex nuttallii (lb/ac)(% of total)	210(52%)	212(46%)	114(17%)	79(26%)	68(27%)	126(38%)	0	0
Artemisia tridentata (lb/ac)(% of total)	Trace	Trace	9(1%)	Trace	0	0	87(47%)	96(43%)
Opuntia polyacantha (lb/ac)(% of total)	68(17%)	184(40%)	481(73%)	187(61%)	0	22(7%)	31(17%)	67(30%)
Range Condition (% - class)	62%-Good	54%-Good	24%-Poor	34%-Fair	34%-Fair	46%-Fair	40%-Fair	29%-Fair
Vigor of Key Species:								
Poa secunda	232(P<0.1)	212	--	--	--	--	--	--
Atriplex nuttallii	.1021(NS)	.1152	--	--	.1079(P<0.2)	.2088	--	--
Agropyron smithii	--	--	--	--	--	--	159(P<0.01)	142
Litter (lb/ac)	23	17	80	37	327	13	725	212
Infiltration (mm/min)								
First 5 min.	1.13	1.00	1.20	1.30	0.60	0.20	1.20	1.27
Second 5 min.	--	0.60	0.87	0.80	0.07	0.13	1.43	1.20
Third 5 min	--	--	0.70	0.80	0.27	0.27	1.07	0.53

Table 2. Vegetation characteristics and soil water infiltration rates on shallow clay range sites grazed by rest-rotation systems compared to other past treatments.

	Treatment Comparisons							
	Site No. 2		Site No. 8		Site No. 14		Site No. 15	
Comparison Parameters	5-Pasture Rest-Rotation (10 years)	Season-long Grazing	4-Pasture Rest-Rotation (12 years)	Season-long Grazing	5-Pasture Rest-Rotation (9 years)	Exclosure	5-Pasture Rest-Rotation (9 years)	Winter Grazing
Total Production (lb/ac)	385	400	252	165	186	217	304	235
Desirable Grasses (lb/ac)(% of total)	82(21%)	194(49%)	73(29%)	54(33%)	22(12%)	37(17%)	92(30%)	109(46%)
Atriplex nuttallii (lb/ac)(% of total)	3(1%)	7(2%)	0	0	40(22%)	51(24%)	49(16%)	47(20%)
Artemisia tridentata (lb/ac)(% of total)	237(62%)	182(45%)	71(28%)	0	117(63%)	125(58%)	158(52%)	73(31%)
Opuntia polyacantha (lb/ac)(% of total)	26(7%)	5(1%)	18(7%)	26(16%)	6(3%)	2(1%)	0	0
Range Condition (% - class)	36%-Fair	55%-Good	34%-Fair	43%-Fair	42%-Fair	47%-Fair	53%-Good	74%-Good
Vigor of Key Species:								
Agropyron smithii	143($P<0.1$)	135	92 (NS)	96	141 (NS)	142	135 (NS)	134
Atriplex nuttallii	--	--	--	--	0.240($P<0.2$)	0.289	--	--
Litter (lb/ac)	373	305	17	10	156	204	67	123
Infiltration (mm/min)								
First 5 min.	3.80	2.73	1.13	1.27	1.47	1.23	1.13	1.47
Second 5 min.	3.23	1.73	0.80	0.70	1.37	1.27	0.70	0.83
Third 5 min.	--	--	0.60	0.37	1.20	0.53	0.67	0.90

Table 3. Vegetation characteristics and soil water infiltration rates on clayey range sites grazed by rest-rotation systems compared to other past treatments.

Comparison Parameters	Site No. 6: 4-Pasture Rest-Rotation (12 years)	Site No. 6: No Grazing	Site No. 7: 4-Pasture Rest-Rotation (12 years)	Site No. 7: No Grazing	Site No. 9: 4-Pasture Rest-Rotation (12 years)	Site No. 9: Seasonlong Grazing	Site No. 27: 6-Pasture Rest-Rotation (9 years)	Site No. 27: Yearlong Grazing
Total Production (lb/ac)	240	242	105	130	281	236	115	112
Desirable Grasses (lb/ac)(% of total)	66(27%)	131(54%)	44(42%)	70(54%)	110(39%)	111(47%)	66(57%)	57(51%)
Atriplex nuttallii (lb/ac)(% of total)	25(10%)	19(8%)	0	0	11(4%)	20(8%)	0	2(2%)
Artemisia tridentata (lb/ac)(% of total)	52(22%)	30(12%)	0	0	0	0	0	0
Opuntia polyacantha (lb/ac)(% of total)	13(5%)	11(4%)	26(25%)	27(21%)	137(49%)	84(36%)	48(42%)	57(51%)
Range Condition (% - class)	41%-Fair	66%-Good	24%-Poor	42%-Fair	15%-Poor	16%-Poor	48%-Fair	38%-Fair
Vigor of Key Species:								
Atriplex nuttallii	0.201($P<.05$)	0.256	--	--	--	--	--	--
Agropyron smithii	121 (NS)	122	108($P<0.01$)	122	--	--	85($P<0.2$)	92
Bouteloua gracilis	--	--	45 (NS)	45	48 (NS)	49	--	--
Litter (lb/ac)	132	330	12	32	50	31	48	136
Infiltration (mm/min)								
First 5 min.	0.90	0.73	1.32	1.88	1.07	0.97	1.50	2.07
Second 5 min.	0.63	0.50	0.88	1.40	0.57	0.37	1.10	1.40
Third 5 min.	0.50	0.47	0.92	1.08	0.50	0.20	0.90	1.10

Treatment Comparisons

Table 4. Vegetation characteristics and soil water infiltration rates on clayey range sites grazed by rest-rotation grazing systems compared to other past treatments.

Comparison Parameters	Treatment Comparisons							
	Site No. 17		Site No. 19		Site No. 20		Site No. 21	
	5-Pasture Rest-Rotation (8 years)	June-September Grazing	3-Pasture Rest-Rotation (8 years)	April-September Grazing	3-Pasture Rest-Rotation (8 years)	May-October Grazing	3-Pasture Rest-Rotation (8 years)	May-October Grazing
Total Production (lb/ac)	406	302	186	233	220	261	296	129
Desirable Grasses (lb/ac)(% of total)	157(39%)	43(14%)	98(53%)	84(36%)	90(41%)	70(27%)	155(52%)	47(36%)
Atriplex nuttallii (lb/ac)(% of total)	0	0	0	0	0	0	0	0
Artemisia tridentata (lb/ac)(% of total)	68(17%)	117(39%)	57(31%)	56(24%)	106(48%)	110(42%)	130(44%)	55(43%)
Opuntia polyacantha (lb/ac)(% of total)	0	0	Trace	79(34%)	16(7%)	76(29%)	0	11(9%)
Range Condition (% - class)	49%-Fair	29%-Fair	51%-Good	38%-Fair	47%-Fair	33%-Fair	58%-Good	44%-Fair
Vigor of Key Species:								
Agropyron smithii	--	--	--	--	144($P<0.05$)	133	166($P<0.01$)	141
Stipa viridula	--	--	336($P<0.01$)	282	--	--	--	--
Litter (lb/ac)	423	284	110	277	189	527	137	29
Infiltration (mm/min)								
First 5 min.	3.33	2.67	1.00	0.30	2.04	0.13	0.90	0.40
Second 5 min.	2.53	2.27	0.90	0.27	1.24	0.27	0.73	0.47
Third 5 min.	2.27	1.90	0.77	0.27	1.60	0.07	0.57	0.33

Table 5. Vegetation characteristics and soil water infiltration rates on clayey range sites receiving different grazing treatments in the past.

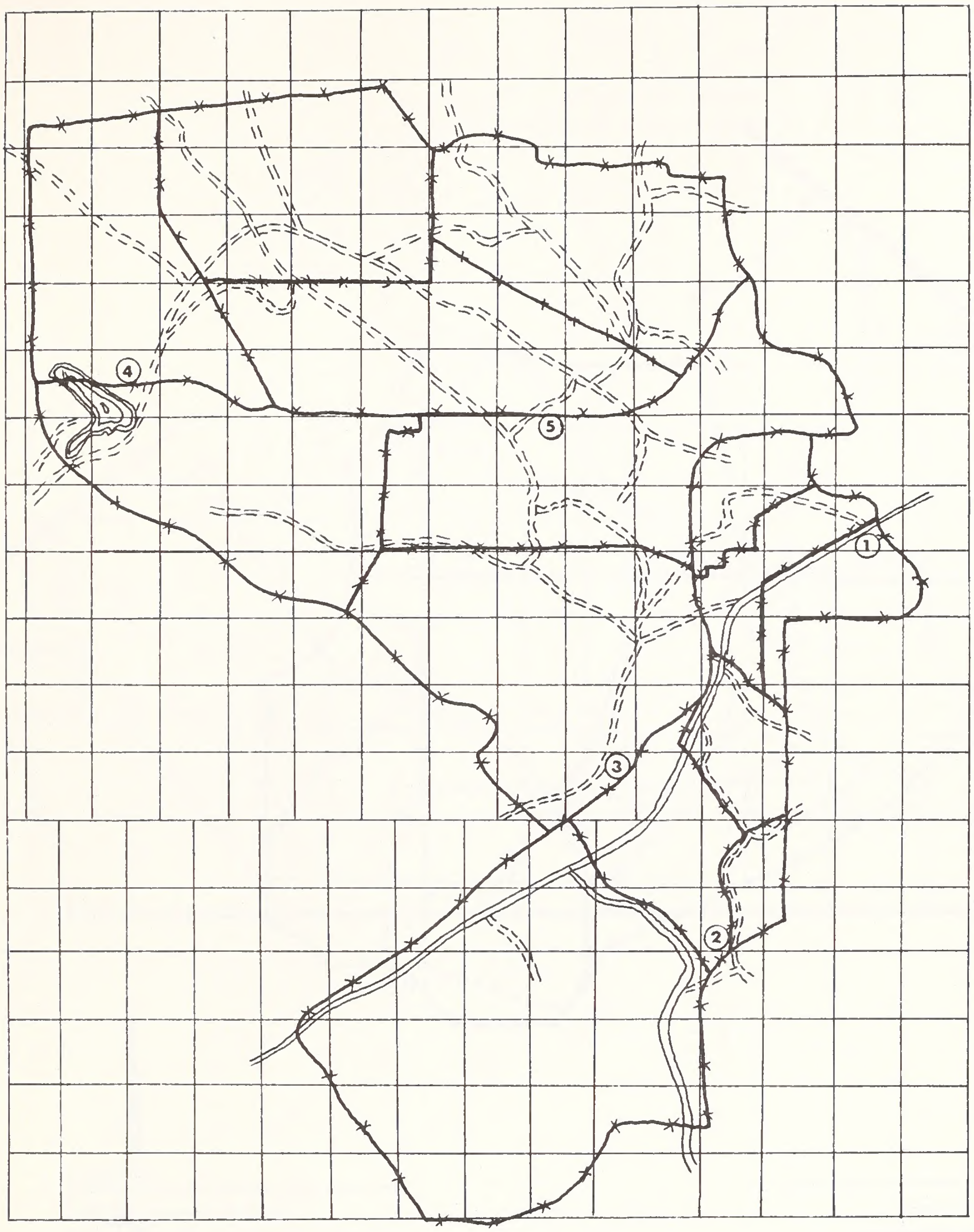
	Treatment Comparisons					
	Site No. 10		Site No. 11		Site No. 22	
Comparison Parameters	Seasonlong Grazing	Fall-Spring Grazing	Seasonlong Grazing	April-June Grazing	5-Pasture Rest-Rotation (8 years)	June-September Grazing
Total Production (lb/ac)	128	85	267	285	570	457
Desirable Grasses (lb/ac)(% of total)	47(36%)	42(50%)	42(16%)	70(25%)	215(38%)	52(11%)
Atriplex nuttallii (lb/ac)(% of total)	0	0	0	0	0	0
Artemisia tridentata (lb/ac)(% of total)	1(1%)	7(7%)	186(70%)	156(55%)	323(57%)	358(82%)
Opuntia polyacantha (lb/ac)(% of total)	0	Trace	21(8%)	36(13%)	Trace	0
Range Condition (% - class)	36%-Fair	31%-Fair	18%-Poor	29%-Fair	44%-Fair	20%-Poor
Vigor of Key Species:						
Agropyron smithii	96($P<0.05$)	104	103($P<0.05$)	113	--	--
Bouteloua gracilis	41($P<0.2$)	44	--	--	--	--
Agropyron spicatum	--	--	--	--	40($P<0.01$)	5
Litter (lb/ac)	322	129	149	137	311	456
Infiltration (mm/min)						
First 5 min.	3.03	3.23	0.77	0.27	1.80	0.57
Second 5 min.	1.93	1.90	0.37	0.27	1.67	0.56
Third 5 min.	1.70	1.53	0.33	0.33	1.33	0.63

Table 6. Vegetation characteristics and soil water infiltration rates on silty range sites receiving different grazing treatments in the past.

Comparison Parameters	Site No. 23: 2-Pasture Deferred-Rotation (6 years)	Site No. 23: Winter Grazing	Site No. 24: 2-Pasture Deferred-Rotation (6 years)	Site No. 24: May-October Grazing	Site No. 25: 6-Pasture Rest-Rotation (9 years)	Site No. 25: Yearlong Grazing	Site No. 26: 6-Pasture Rest-Rotation (9 years)	Site No. 26: Winter Grazing
Total Production (lb/ac)	193	235	228	253	143	222	145	130
Desirable Grasses (lb/ac)(% of total)	120(62%)	153(65%)	173(76%)	171(68%)	92(65%)	51(23%)	122(84%)	78(60%)
Atriplex nuttallii (lb/ac)(% of total)	0	0	Trace	0	3(2%)	0	0	0
Artemisia tridentata (lb/ac)(% of total)	Trace	0	0	0	0	0	0	0
Opuntia polyacantha (lb/ac)(% of total)	36(19%)	28(12%)	0	14(5%)	13(9%)	72(32%)	3(2%)	22(17%)
Range Condition (% - class)	54%-Good	56%-Good	60%-Good	68%-Good	57%-Good	23%-Poor	41%-Fair	44%-Fair
Vigor of Key Species:								
Stipa comata	133(P<0.01)	111	119(P<0.05)	110	114(P<0.05)	106	114(P<0.05)	106
Bouteloua gracilis	67 (NS)	62	--	--	--	--	--	--
Agropyron smithii	--	--	111 (NS)	108	--	--	--	--
Litter (lb/ac)	194	324	90	184	104	110	48	136
Infiltration (mm/min)								
First 5 min.	0.77	1.03	1.23	1.10	2.47	2.80	4.23	4.20
Second 5 min.	1.03	0.60	1.03	0.93	1.67	1.73	3.07	2.87
Third 5 min.	0.60	0.70	0.93	0.73	1.37	1.73	2.77	2.73

Table 7. Vegetation characteristics and soil water infiltration rates on silty and saline-upland range sites receiving different grazing treatments in the past.

Comparison Parameters	Treatment Comparisons							
	Site No. 5 (Saline-upland)		(Site No. 12 (Silty)		Site No. 16 (Silty)		Site No. 18 (Silty)	
	4-Pasture Rest-Rotation (4 years)	3-Pasture Rest-Rotation (3 years)	Fall Grazing	Seasonlong Grazing	5-Pasture Rest-Rotation (8 years)	August-November Grazing	5-Pasture Rest-Rotation (8 years)	December-April Grazing
Total Production (lb/ac)	90	94	273	71	323	382	256	216
Desirable Grasses (lb/ac)(% of total)	8(9%)	9(9%)	147(63%)	54(76%)	144(45%)	122(32%)	90(35%)	115(53%)
Atriplex nuttallii (lb/ac)(% of total)	13(14%)	5(5%)	0	0	0	0	0	2(1%)
Artemisia tridentata (lb/ac)(% of total)	0	0	0	0	93(29%)	184(48%)	101(39%)	32(15%)
Opuntia polyacantha (lb/ac)(% of total)	0	0	32(14%)	0	0	0	20(8%)	41(19%)
Range Condition (% - class)	43%-Fair	29%-Fair	43%-Fair	45%-Fair	16%-Poor	30%-Fair	30%-Fair	47%-Fair
Vigor of Key Species:								
Agropyron smithii	127(P<0.01)	113	116(P<0.01)	102	--	--	122(P<0.05)	112
Bouteloua gracilis	--	--	57(P<0.01)	37	--	--	--	--
Calamagrostis montanaensis	--	--	--	--	166(P<0.05)	152	--	--
Koeleria cristata	--	--	--	--	--	--	60(P<0.2)	70
Litter (lb/ac)	17	15	320	337	48	129	89	162
Infiltration (mm/min)								
First 5 min.	1.77	0.39	3.70	2.77	2.60	1.37	1.53	1.30
Second 5 min.	0.80	0.30	2.60	2.30	1.87	1.13	0.90	0.90
Third 5 min.	1.20	0.10	2.27	1.97	1.27	0.77	0.67	0.77



Legend

Fence
Road
Primitive Road
Section Line
Study Site

Figure 1. Locations of study sites 1-5 in Miller Coulee, Lower Little Beaver, and Lewis Reservoir allotments.

Figure 2. Locations of study sites 6-9 in the Lavelle Creek allotment.

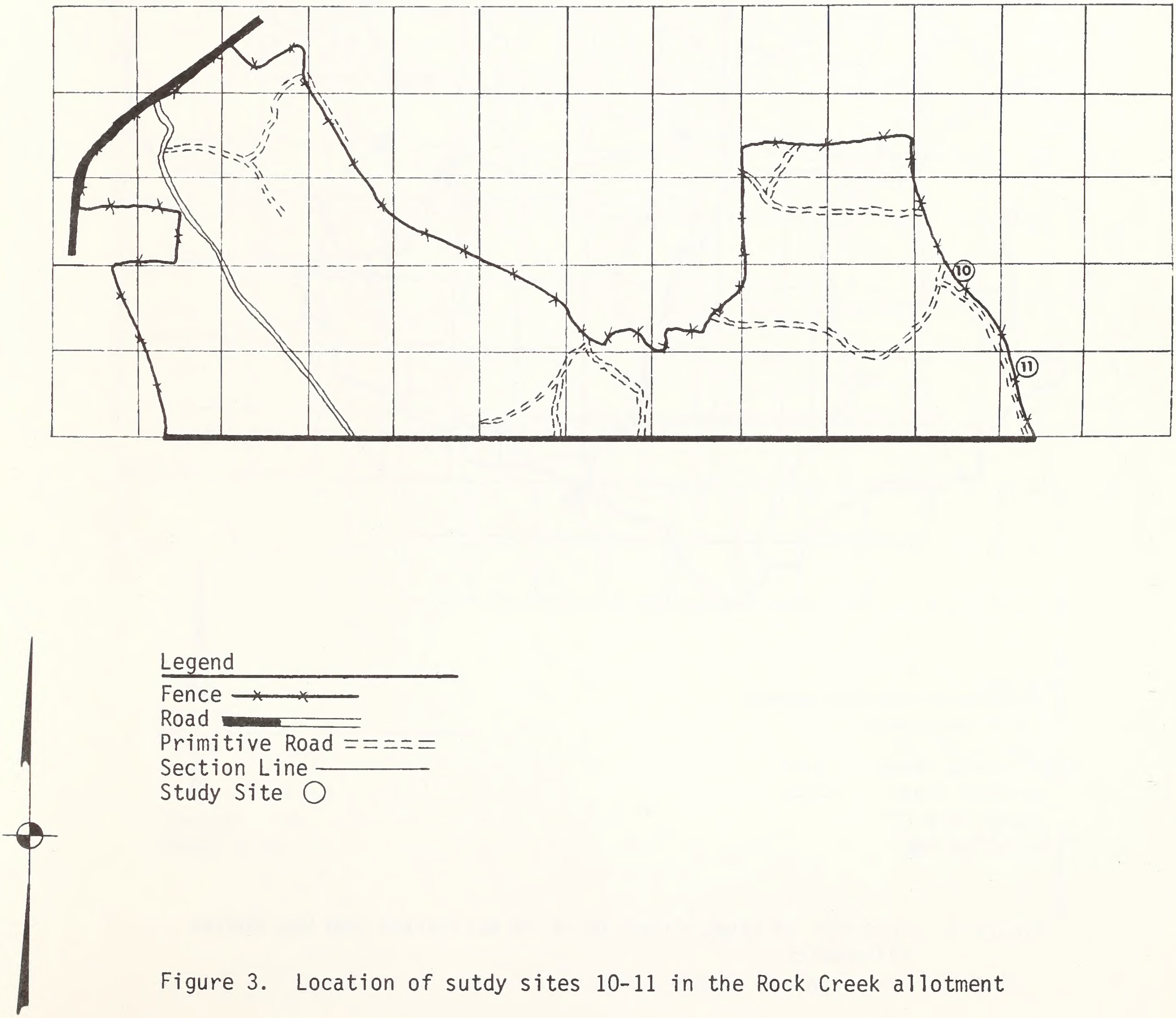


Figure 3. Location of sutdy sites 10-11 in the Rock Creek allotment

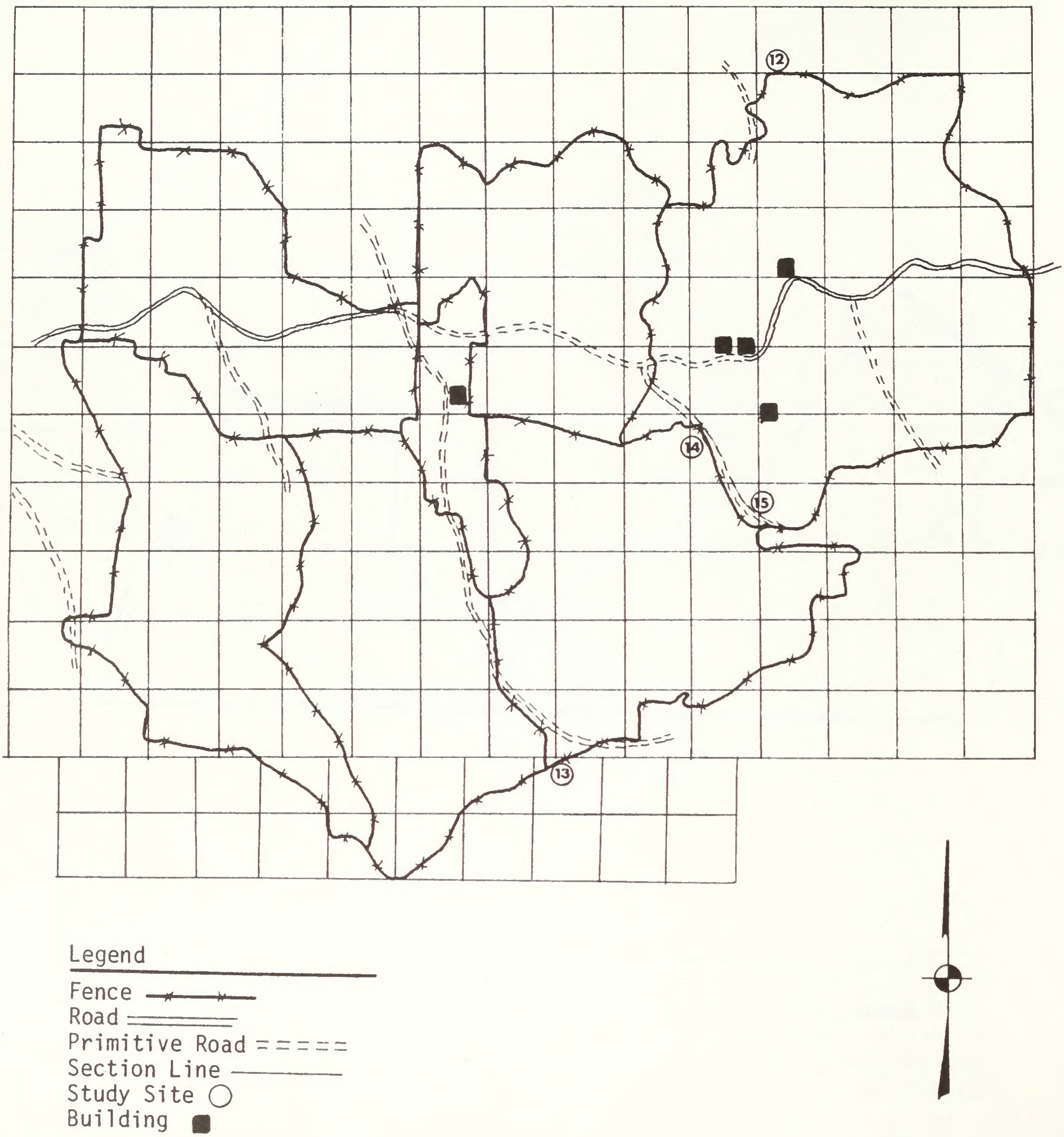


Figure 4. Location of study sites 12-15 in Bullwacker and Hay Coulee allotments.

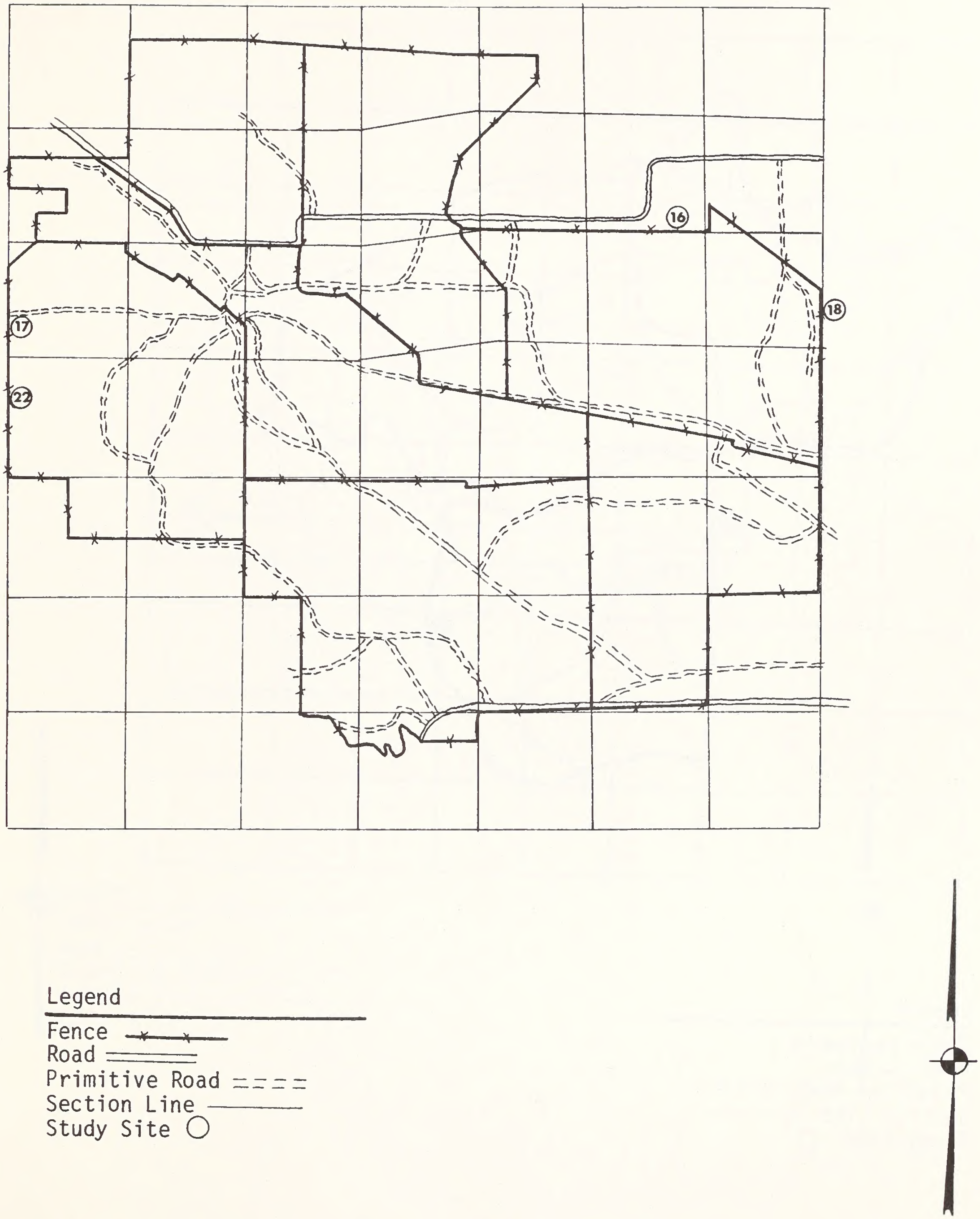
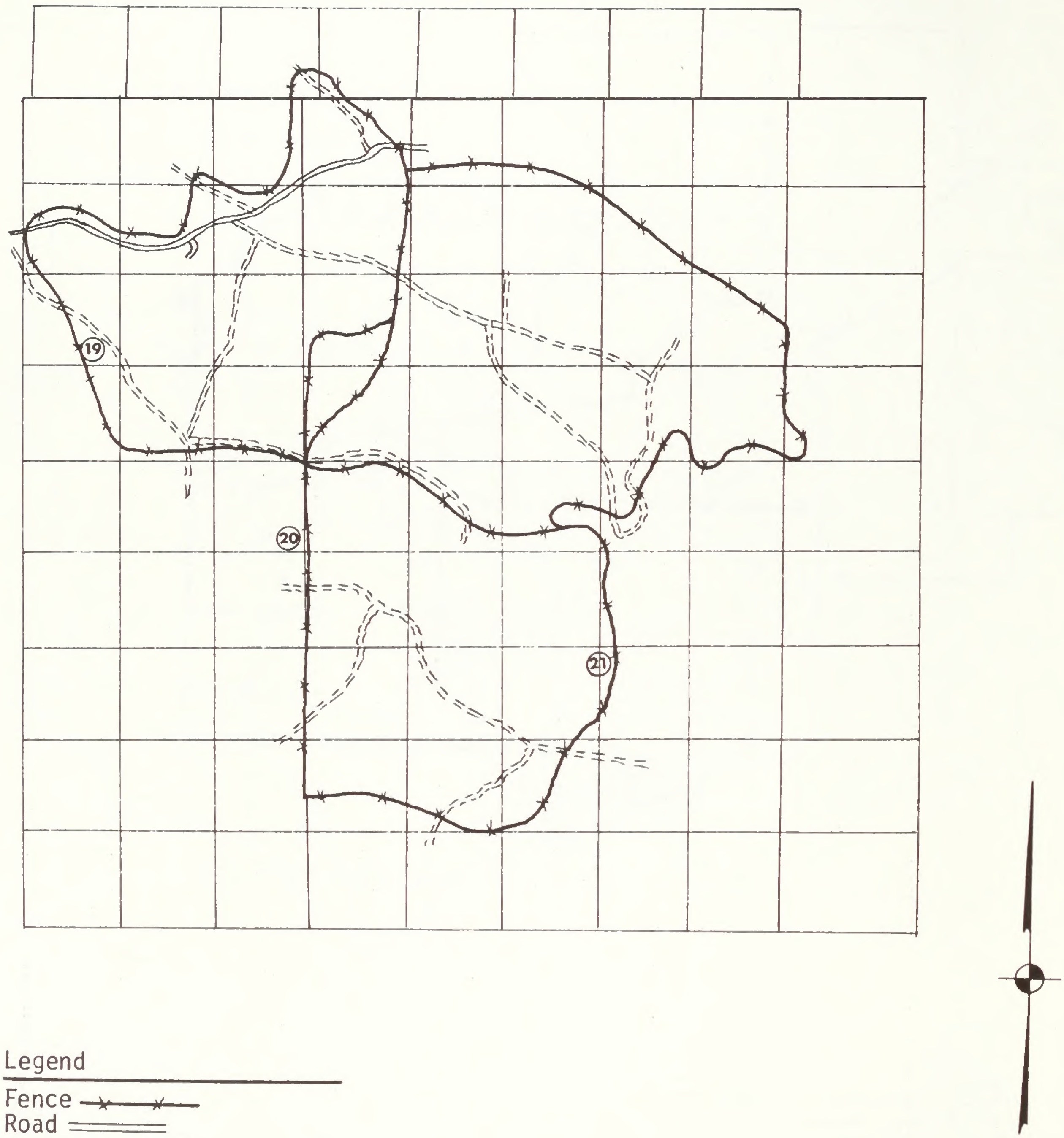


Figure 5. Location of study sites 16-18 and 22 in the King allotment.



Legend

Fence

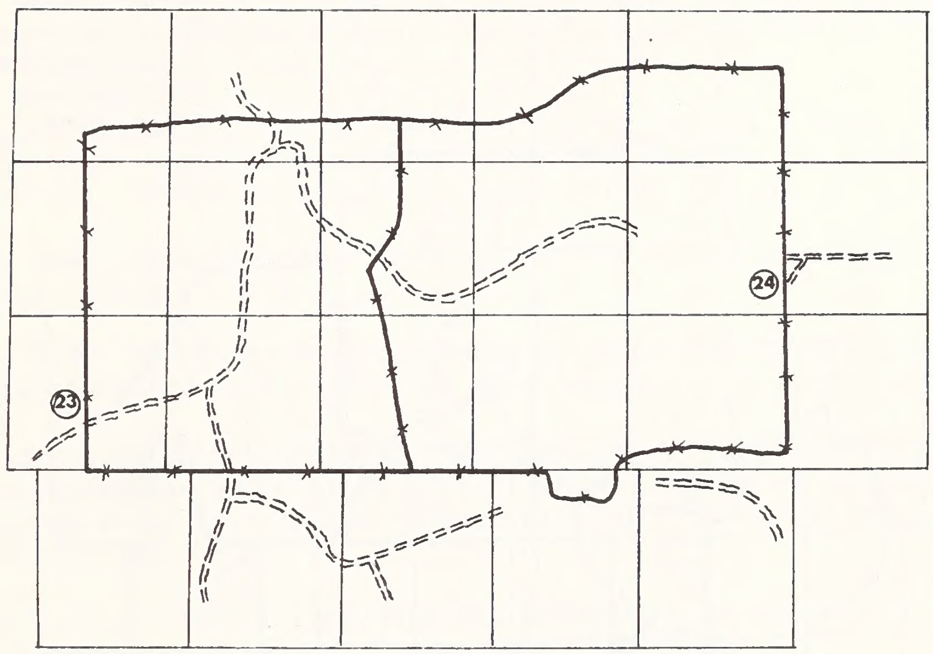
Road

Primitive Road

Section Line

Study Site

Figure 6. Location of study sites 19-21 in the Iverson allotment.



Legend

Fence

Road

Primitive Road

Section Line

Study Site

Figure 7. Location of study sites 23-24 in the Snell allotment.

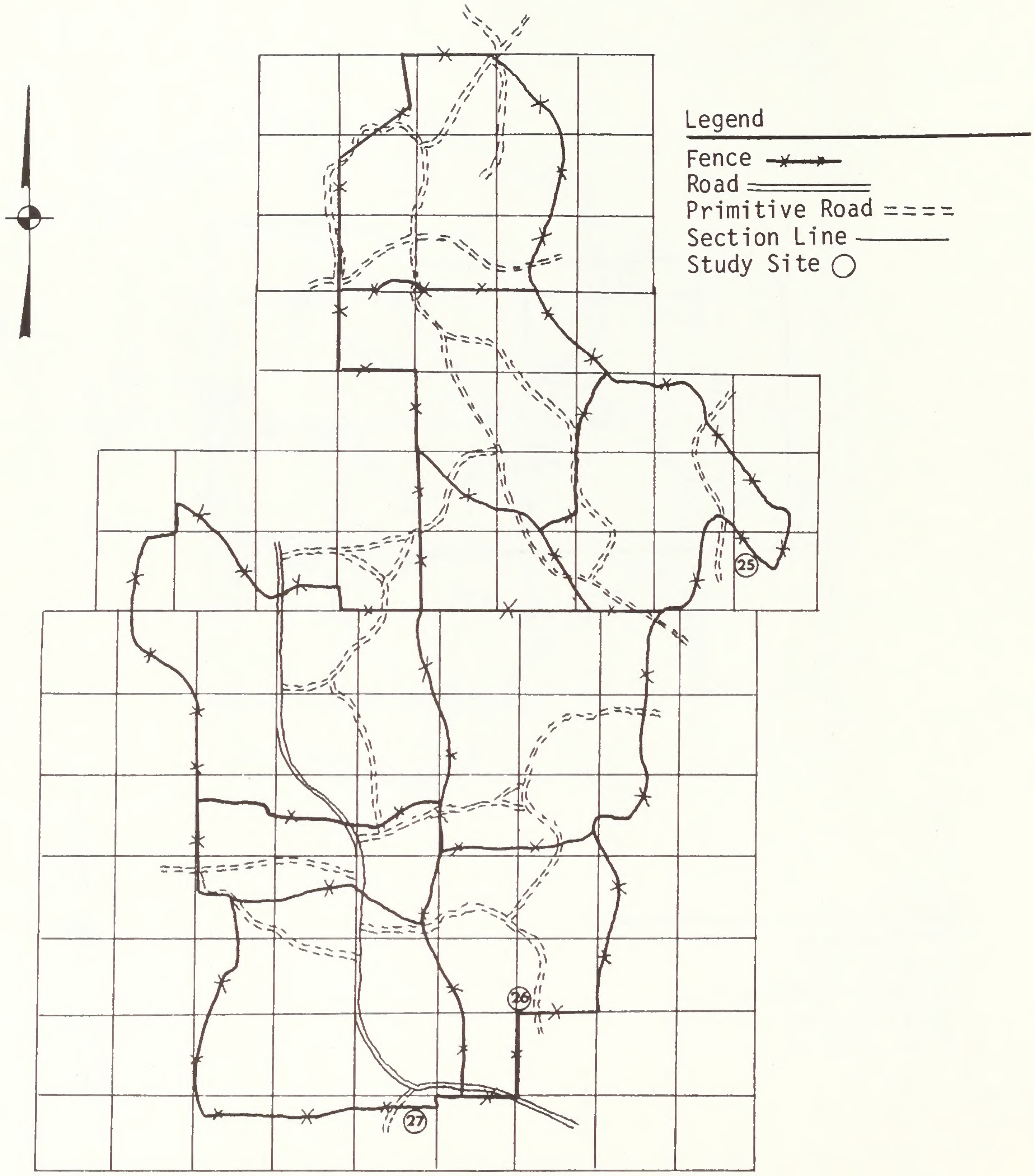


Figure 8. Location of study sites 25-27 in the Burgess allotment.

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APPENDICES

Appendix 1. Summary of the allotments used in the study.

BLM Resource Area	Allotment Name	Grazing System or Schedule	Years in Operation	Acreage
Havre	Bullwacker	5-pasture rest-rotation	9	21,800
	Hay Coulee	a) Winter use b) Fall use c) 3-pasture rest-rotation	7	16,500
Phillips	Lavelle Creek	4-pasture rest-rotation	12	10,800
	Rock Creek	Seasonlong 5/15 - 11/25	--	7,000
Valley	Lewis Reservoir	5-pasture rest-rotation	10	15,600
	Miller Coulee	4-pasture rest-rotation	4	23,900
	Lower Little Beaver	3-pasture rest-rotation	3	24,200
Judith	King	5-pasture rest-rotation	8	19,200
	Iverson	3-pasture rest-rotation	8	20,800
Big Dry	Burgess	6-pasture rest-rotation	9	25,160
	Snell	2-pasture deferred-rotation	6	6,738

Appendix 2. Plant species composition (lb/ac, %) on the study sites.

Site No. 1

	5-Pasture Rest-Rotation (10 years)		Season-long Grazing	
	Lb/Ac	%	Lb/Ac	%
Atriplex nuttallii	210.0	52.0	211.5	46.0
Poa secunda	63.0	16.0	27.3	6.0
Agropyron smithii	0	0	0.2	T
Hordeum jubatum	11.6	3.0	5.2	1.0
Helianthus petiolaris	20.9	5.0	4.9	1.0
Aster canescens	3.9	1.0	1.5	T
Opuntia polycantha	68.0	17.0	183.7	40.0
Polygonum sp.	19.2	5.0	10.0	2.0
Lepidium sp.	6.0	1.0	9.4	2.0
Grindelia squarosa	0.8	T	--	--
Artemisia tridentata	0.1	T	1.0	T
Misc. Forbs	1.5	T	2.4	1.0
Totals	405.0		457.1	

Site No. 2

	5-Pasture Rest-Rotation (10 years)		Season-long Grazing	
	Lb/Ac	%	Lb/Ac	%
Agropyron smithii	63.4	16.0	190.4	48.0
Stipa viridula	18.8	5.0	3.8	1.0
Muhlenbergia cuspidata	5.2	1.0	2.4	1.0
Atriplex nuttallii	2.6	1.0	7.3	2.0
Opuntia polycantha	25.8	7.0	5.6	1.0
Artemisia frigida	20.5	5.0	1.6	T
Sphaeralcea coccinea	2.8	1.0	3.2	1.0
Artemisia tridentata	237.4	62.0	181.7	45.0
Vicia americana	3.4	1.0	1.7	T
Achillea millefolium	3.6	1.0	1.5	T
Mis. Forbs	1.5	T	1.2	T
Totals	385.0		400.4	

Appendix 2 -- Continued

Site No. 3

	5-Pasture Rest-Rotation (10 years)		3-Pasture Rest-Rotation (3 years)	
	Lb/Ac	%	Lb/Ac	%
Atriplex nuttallii	114.0	17.0	78.5	26.0
Poa secunda	39.5	6.0	21.4	7.0
Opuntia polycantha	481.0	73.0	186.9	61.0
Artemisia tridentata	8.8	1.0	2.1	1.0
Hordeum jubatum	2.5	T	3.0	1.0
Agropyron smithii	0	0	3.3	1.0
Artemisia frigida	0	0	5.1	2.0
Phlox hoodii	1.0	T	1.0	T
Sporobolus cryptandrus	7.4	1.0	1.0	T
Schedonnardus paniculatus	7.0	1.0	1.0	T
Misc. Forbs	1.8	T	1.8	1.0
Totals	663.0		305.1	

Site No. 4

	5-Pasture Rest-Rotation (3 years)		4-Pasture Rest-Rotation (4 years)	
	Lb/Ac	%	Lb/Ac	%
Hordeum jubatum	86.4	34.1	43.7	13.4
Schedonnardus paniculatus	65.9	26.0	83.0	25.4
Poa secunda	17.4	6.9	18.1	5.5
Atriplex nuttallii	67.8	26.8	125.8	38.4
Artemisia frigida	10.3	4.1	1.7	T
Opuntia polycantha	0	0	21.5	6.6
Agropyron smithii	0	0	7.4	2.3
Grindelia squarosa	0	0	23.8	7.3
Misc. Grasses	0.6	T	0.1	T
Misc. Forbs	4.8	1.9	2.2	1.0
Totals	253.2		327.3	

Appendix 2 -- Continued

Site No. 5

	4-Pasture Rest-Rotation (4 years)		3-Pasture Rest-Rotation (3 years)	
	Lb/Ac	%	Lb/Ac	%
Agropyron smithii	8.25	9.2	8.75	9.3
Muhlenbergia cuspidata	13.20	14.7	9.20	9.7
Erigonum pauciflorum	6.93	7.7	14.85	15.7
Hymenoxys richardsonii	45.14	50.2	54.76	58.0
Atriplex nuttallii	13.00	14.4	4.50	4.8
Schedonnardus paniculatus	0	0	0.61	T
Misc. Forbs	3.45	3.8	1.80	1.9
Totals	89.97		94.47	

Site No. 6

	4-Pasture Rest-Rotation (12 years)		No Grazing	
	Lb/Ac	%	Lb/Ac	%
Artemisia tridenta	51.60	21.5	30.10	12.4
Koeleria cristata	18.40	7.7	23.32	9.6
Atriplex nuttallii	24.50	10.2	18.55	7.7
Schedonnardus paniculatus	3.35	1.4	7.71	3.2
Poa secunda	2.00	T	3.25	1.3
Agropyron smithii	45.58	19.0	104.94	43.4
Gutierrezia sarothrae	12.75	5.3	0.38	T
Oxytropis spp.	22.11	9.2	0.99	T
Opuntia polycantha	12.54	5.2	10.56	4.4
Artemisia frigida	46.00	19.2	32.50	13.4
Sacrobatus vermiculatus	0	0	8.00	3.3
Misc. Forbs	1.40	T	1.80	T
Totals	240.23		242.01	

Appendix 2 -- Continued

Site No. 7

	4-Pasture Rest-Rotation (12 years)		No Grazing	
	Lb/Ac	%	Lb/Ac	%
Agropyron smithii	12.30	11.7	30.00	23.1
Eurotia lanata	2.50	2.4	11.50	8.8
Bouteloua gracilis	25.92	24.7	29.16	22.4
Artemisia frigida	27.60	26.3	20.60	15.8
Koeleria cristata	5.52	5.3	11.04	8.5
Schedonnardus paniculatus	4.69	4.5	0	0
Opuntia polycantha	26.40	25.2	27.06	20.8
Misc. Forbs	0	0	0.60	T
Totals	104.93		129.96	

Site No. 8

	4-Pasture Rest-Rotation (12 years)		Season-long Grazing	
	Lb/Ac	%	Lb/Ac	%
Artemisia frigida	84.18	33.4	70.15	42.6
Agropyron smithii	33.60	13.4	47.40	28.8
Bouteloua gracilis	39.20	15.6	6.80	4.1
Opuntia polycantha	17.62	7.0	25.80	15.7
Schedonnardus parniclatus	3.35	T	0	0
Carex spp.	0.20	T	0	0
Artemisia tridentata	71.28	28.3	0	0
Poa secunda	0	0	0.25	T
Misc. Forbs	0.20	T	0.70	T
Total	251.63		164.50	

Appendix 2 -- Continued

Site No. 9

	4-Pasture Rest-Rotation (12 years)		Season-long Grazing	
	Lb/Ac	%	Lb/Ac	%
Atriplex nuttallii	11.02	3.9	19.75	8.4
Agropyron smithii	16.50	5.9	4.25	1.8
Artemisia frigida	20.00	7.1	20.00	8.5
Boutleoua gracilis	94.50	33.6	106.47	45.0
Schedonnardus paniculatus	1.34	T	0	0
Opuntia polycantha	136.68	48.6	84.40	35.7
Misc. Forbs	1.40	T	1.60	T
Totals	281.44		236.48	

Site No. 10

	Season-long Grazing		Fall-Spring Grazing	
	Lb/Ac	%	Lb/Ac	%
Agropyron smithii	16.50	12.8	11.00	12.9
Koeleria cristata	5.94	4.6	3.30	3.9
Bouteloua gracilis	24.12	18.8	28.14	33.1
Erigonum spp.	6.50	5.1	0	0
Eurotia lanata	9.75	7.6	0	0
Sphaeralceae coccinea	0.34	T	2.01	2.4
Artemisia frigida	56.00	43.6	27.44	32.3
Gutierrezia sarothrae	8.25	6.4	5.25	6.2
Artemisia tridentata	1.00	T	6.50	7.6
Opuntia polycantha	0	0	0.13	T
Misc. Forbs	0	0	1.20	1.4
Totals	128.40		84.97	

Appendix 2 -- Continued

Site No. 11

	Season-long Grazing Lb/Ac	Season-long Grazing %	April-June Grazing Lb/Ac	April-June Grazing %
Agropyron smithii	14.50	5.4	40.00	14.0
Artemisia tridentata	185.76	69.7	156.06	54.8
Hymenoxys richardsonii	0.74	T	0.74	T
Gutierrezia sarothrae	2.50	1.0	7.00	2.5
Schedonnardus paniculatus	1.34	T	1.68	T
Koeleria cristata	19.76	7.4	18.50	6.5
Boutloua gracilis	7.56	2.8	11.34	4.0
Artemisia frigida	12.96	4.9	11.88	4.2
Opuntia polycnatha	21.32	8.0	36.10	12.7
Schaeralceae coccinea	0	0	0.75	T
Misc. Forbs	0.20	T	0.60	T
Totals	266.64		284.65	

Site No. 12

	Fall Grazing Lb/Ac	Fall Grazing %	Season-long Grazing Lb/Ac	Season-long Grazing %
Artemisia frigida	39.38	16.9	12.10	17.0
Agropyron smithii	72.50	31.2	12.00	16.8
Carex filifolia	1.00	T	0	0
Poa secunda	0.50	T	0.25	T
Bouteloua gracilis	74.10	31.8	29.25	41.0
Erigonum spp.	1.20	T	3.60	5.0
Eurotia lanata	4.36	1.9	0	0
Schaeralceae coccinea	7.25	3.1	0.50	T
Opuntia polycantha	31.68	13.6	0	0
Stipa comata	0	0	12.40	17.4
Misc. Forbs	0.80	T	1.20	1.7
Totals	232.77		71.30	

Appendix 2 -- Continued

Site No. 13

	5-Pasture Rest-Rotation (9 years)		Season-long Grazing	
	Lb/Ac	%	Lb/Ac	%
Artemisia tridentata	86.95	46.6	96.20	43.0
Agropyron smithii	53.20	28.5	35.70	16.0
Potentilla pennsylvanica	12.10	6.5	16.94	7.6
Poa secunda	3.25	1.7	0	0
Opuntia polycantha	31.01	16.6	66.66	29.8
Agropyron spicatum	0	0	7.20	3.2
Misc. Forbs.	0.20	T	0.80	T
Totals	186.71		223.50	

Site No. 14

	5-Pasture Rest-Rotation (9 years)		Exclosure	
	Lb/Ac	%	Lb/Ac	%
Atriplex nuttallii	40.42	21.7	51.17	23.6
Artemisia tridentata	117.30	63.1	124.95	57.6
Agropyron smithii	22.05	11.9	37.10	17.1
Opuntia polycantha	5.98	3.2	3.22	1.5
Misc. Forbs	0.20	R	0.20	T
Totals	185.95		216.74	

Site No. 15

	5-Pasture Rest-Rotation (9 years)		Winter Grazing	
	Lb/Ac	%	Lb/Ac	%
Artemisia tridentata	158.12	52.0	73.03	31.1
Agropyron smithii	91.80	30.2	108.80	46.3
Atriplex nuttallii	48.76	16.0	47.38	20.1
Potentilla pennsylvanica	4.84	1.6	4.23	1.8
Sphaeralceae coccinea	0	0	1.75	T
Misc. Forbs	0.40	T	0	0
Totals	303.92		235.19	

Appendix 2 -- Continued

Site No. 16

	5-Pasture Rest-Rotation (8 years)		August-November Grazing	
	Lb/Ac	%	Lb/Ac	%
Gutierrezia sarothrae	25.20	7.8	16.20	4.2
Agropyron smithii	19.47	6.0	75.23	19.7
Calamagrostis montanensis	124.96	38.7	46.86	12.3
Chrysothamnus viscidiflorus	17.50	5.4	17.75	4.6
Artemisia spp.	93.12	28.8	184.32	48.2
Thermopsis rhombifolia	31.50	9.8	40.00	10.5
Achillea millefolium	1.00	0.3	0	0
Rosa spp.	9.60	3.0	0	0
Erigonum pauciflorum	0.60	0.2	0	0
Calamovilfa longifolia	0	0	0.30	T
Misc. Forbs	0	0	1.50	T
Totals	322.95		382.16	

Site No. 17

	5-Pasture Rest-Rotation (8 years)		June-September Grazing	
	Lb/Ac	%	Lb/Ac	%
Agropyron spicatum	128.80	31.7	27.30	9.0
Artemisia tridentata	68.40	16.9	117.30	38.9
Comandra umbellata	79.92	19.7	13.68	4.5
Gutierrezia sarothrae	33.90	8.4	34.20	11.3
Artemisia frigida	18.76	4.6	6.03	2.0
Calamogrostis montanensis	1.42	0.4	5.68	1.9
Agropyron smithii	12.10	3.0	3.54	1.2
Koeleria cristata	8.50	2.1	2.25	1.0
Misc. Grasses	0.25	T	0	0
Stipa comata	1.00	T	0	0
Thermopsis rhombifolia	14.25	3.5	51.00	16.9
Bouteloua gracilis	4.69	1.2	4.02	1.3
Achillea millefolium	6.50	1.6	0.25	T
Eurotia lanata	2.25	T	0.75	T
Chrysothamnus viscidiflorus	25.00	6.2	33.50	11.1
Rosa spp.	0	0	0.30	T
Misc. Forbs	0	0	1.75	T
Totals	405.74		301.55	

Appendix 2 -- Continued

Site No. 18

	5-Pasture Rest-Rotation (8 years)		December-April Grazing	
	Lb/Ac	%	Lb/Ac	%
Artemisia tridentata	100.80	39.4	31.92	14.8
Opuntia polycantha	19.72	7.7	40.50	18.7
Agropyron smithii	38.00	14.9	65.50	30.3
Koeleria cristata	31.62	12.4	37.20	17.2
Bouteloua gracilis	20.44	8.0	12.40	5.7
Artemisia frigida	27.60	10.8	20.10	9.3
Gutierrezia sarothrae	16.53	6.5	5.70	2.6
Sphaeralceae coccinea	1.00	T	0.25	T
Atriplex nuttallii	0	0	2.66	1.2
Totals	255.71		216.23	

Site No. 19

	3-Pasture Rest-Rotation (8 years)		April-September Grazing	
	Lb/Ac	%	Lb/Ac	%
Artemisia tridentata	57.00	30.7	56.40	5.0
Stipa viridula	44.66	24.0	27.27	11.9
Agropyron smithii	38.94	21.0	14.16	6.1
Carex filifolia	1.67	1.0	4.69	2.0
Poa spp.	14.50	7.8	14.00	6.0
Commandra umbellata	3.75	2.0	1.50	T
Chrysothamnus nauseouses	22.00	11.8	0	0
Opuntia polycantha	1.00	T	79.00	33.9
Muhlenbergia cuspidata	1.33	T	3.35	1.4
Agropyron spicatum	0	0	28.70	12.3
Sphaeralceae coccinea	0	0	1.20	T
Misc. Forbs	1.00	T	2.60	1.1
Totals	185.85		233.32	

Appendix 2 -- Continued

Site No. 20

	3-Pasture Rest-Rotation (8 years)		May-October Grazing	
	Lb/Ac	%	Lb/Ac	%
Artemisia tridentata	106.40	48.3	110.32	42.2
Stipa viridula	46.97	21.3	0	0
Agropyron smithii	39.53	17.9	69.01	26.4
Commandra umbellata	6.00	2.7	2.25	1.0
Sphaeralceae coccinea	0.60	T	0.40	T
Opuntia polycnatha	15.56	7.1	75.75	29.0
Poa secunda	3.50	1.6	1.00	T
Chenopodium spp.	0	0	1.50	T
Misc. Forbs	1.80	1.0	1.20	T
Totals	220.36		261.43	

Site No. 21

	3-Pasture Rest-Rotation (8 years)		May-October Grazing	
	Lb/Ac	%	Lb/Ac	%
Artemisia tridentata	129.92	43.8	55.44	42.9
Agropyron smithii	71.02	24.0	41.54	32.1
Agropyron spicatum	35.70	12.0	0	0
Commandra umbellata	8.00	2.7	3.75	2.9
Koeleria cristata	9.89	3.3	0	0
Muhlenbergia cuspidata	22.78	7.7	3.02	2.3
Stipa viridula	15.64	5.3	0.67	T
Schedonnardus paniculatus	0.75	T	0	0
Poa secunda	0.07	T	0.07	T
Chyrsothamnus viscidiflorus	0	0	0.50	T
Erigonum spp.	0	0	1.20	1.0
Hymenoxys richardsonii	0	0	0.80	T
Gutierrezia sarothrae	0	0	2.50	1.9
Poa spp.	0	0	2.50	1.9
Rhus trilobata	0	0	1.80	1.4
Sphaeralceae coccinea	0	0	0.90	T
Opuntia polycantha	0	0	11.25	8.7
Astragalus spp.	0	0	0.90	T
Misc. Forbs	2.60	1.0	2.40	1.9
Totals	296.38		129.24	

Appendix 2 -- Continued

Site No. 22

	5-Pasture Rest-Rotation (8 years)		June-September Grazing	
	Lb/Ac	%	Lb/Ac	%
Artemisia tridentata	323.40	56.8	357.60	81.8
Agropyron spicatum	190.40	33.4	36.80	8.0
Stipa viridula	12.60	2.2	3.00	T
Stipa comata	2.50	T	0	0
Artemisia frigida	18.09	3.2	7.29	1.6
Opuntia polycantha	3.20	T	0	0
Gutierrezia sarothrae	2.75	T	6.00	1.3
Sphaeralceae coccinea	0.75	T	3.50	T
Koeleria cristata	6.00	1.0	8.04	1.8
Agropyron smithii	3.30	T	3.60	T
Achillea millefolium	5.00	1.0	6.00	1.3
Taraxicum officinale	0.25	T	0.75	T
Schedonnardus paniculatus	0	0	3.60	T
Carex spp.	0	0	1.80	T
Bouteloua gracilis	0	0	1.01	T
Misc. Forbs	1.50	T	1.75	T
Totals	569.74		459.04	

Site No. 23

	2-Pasture Deferred-Rotation (6 years)		Winter Grazing	
	Lb/Ac	%	Lb/Ac	%
Stipa comata	77.49	40.2	97.68	41.6
Carex filifolia	22.05	11.4	42.84	18.2
Agropyron smithii	35.00	18.2	36.40	15.5
Bouteloua gracilis	7.75	4.0	18.50	7.9
Schaefalceae coccinea	1.25	T	5.00	2.1
Opuntia polycantha	36.07	18.7	28.27	12.0
Artemisia frigida	10.72	5.6	0.77	T
Artemisia tridentata	0.28	T	0	0
Sporobolus cryptandrus	1.50	T	0	0
Erigonum spp.	0	0	0.30	T
Artemisia cana	0	0	2.50	1.1
Misc. Forbs	0.50	T	2.50	1.1
Totals	192.61		234.76	

Appendix 2 -- Continued

Site No. 24

	2-Pasture Deferred-Rotation (6 years)		May-October Grazing	
	Lb/Ac	%	Lb/Ac	%
Stipa comata	104.58	45.9	78.12	30.8
Agropyron smithii	57.40	25.2	74.90	29.6
Carex filifolia	45.36	19.9	44.73	17.6
Artemisia frigida	0.34	T	19.43	7.7
Boutleoua gracilis	10.00	4.4	9.25	3.6
Koeleria cristata	0.50	T	9.00	3.6
Opuntia polycantha	0	0	13.74	5.4
Astragalus spp.	8.19	3.6	2.21	1.0
Poa spp.	0	0	0.50	T
Atriplex nuttallii	0.60	T	0	0
Taraxicum spp.	0.50	T	0	0
Misc. Forbs	0.25	T	1.50	T
Totals	227.72		253.38	

Site No. 25

	6-Pasture Rest-Rotation (9 years)		Year-long Grazing	
	Lb/Ac	%	Lb/Ac	%
Stipa comata	55.13	38.5	32.45	14.6
Agropyron smithii	18.29	12.8	3.84	1.7
Bouteloua gracilis	15.50	10.8	13.50	6.1
Koeleria cristata	3.50	2.4	1.00	T
Opuntia polycantha	13.40	9.4	71.69	32.3
Artemisia frigida	17.42	12.2	59.63	26.9
Distichlis stricta	2.36	1.6	38.94	17.6
Carex filifolia	12.73	8.9	0	0
Atriplex nuttallii	3.00	2.1	0	0
Astragalus spp.	1.89	1.3	0	0
Sphaeralceae coccinea	0	0	0.75	T
Totals	143.22		221.82	

Appendix 2 -- Continued

Site No. 26

	6-Pasture Rest-Rotation (9 years) Lb/Ac	%	Winter Grazing Lb/Ac	%
Stipa comata	111.51	76.8	66.15	50.9
Bouteloua gracilis	5.00	3.4	5.50	4.2
Carex filifolia	16.08	11.1	21.78	16.8
Agropyron smithii	5.02	3.5	6.49	5.0
Opuntia polycantha	2.34	1.6	22.11	17.0
Misc. Forbs	5.25	3.6	8.00	6.2
Totals	145.20		130.03	

Site No. 27

	6-Pasture Rest-Rotation (9 years) Lb/Ac	%	Year-long Grazing Lb/Ac	%
Agropyron smithii	47.20	40.9	31.86	28.5
Bouteloua gracilis	17.00	14.7	18.50	16.5
Sphaeralceae coccinea	0.50	T	0	0
Koeleria cristata	1.50	1.3	2.50	2.2
Opuntia polycantha	48.24	41.8	56.62	50.6
Artemisia frigida	0.67	T	0	0
Astragalus spp.	0.32	T	0	0
Atriplex nuttallii	0	0	2.40	2.2
Totals	115.43		111.88	

Appendix 3. Scientific and common names of species mentioned in the text.

Grasses and Sedges:

Agropyron dasystachyum. . . . . Thickspike wheatgrass

Agropyron smithii . . . . Western wheatgrass

Agropyron spicatum. . . . . Bluebunch wheatgrass

Bouteloua gracilis. . . . . Blue grama

Buchloe dactyloides . . . . Buffalograss

Calamagrostis montanensis . . . . Plains reedgrass

Calamovilfa longifolia. . . . . Prairie sandreed

Carex filifolia . . . . Threadleaf sedge

Distichlis stricta. . . . . Inland saltgrass

Hordeum jubatum . . . . Foxtail barley

Koeleria cristata . . . . Prairie junegrass

Muhlenbergia cuspidata. . . . . Plains muhly

Poa cusickii. . . . . Cusick's bluegrass

Poa secunda . . . . Native bluegrass

Schedonnardus paniculatus . . . . Tumblegrass

Sporobolus cryptandrus. . . . . Sand dropseed

Stipa comata. . . . . Needle-and-thread

Stipa spartea . . . . Porcupine grass

Stipa viridula. . . . . Green needlegrass

Forbs:

Achillea millefolium. . . . . Western yarrow

Artemisia frigida . . . . Fringed sage

Aster canescens . . . . Hoary aster

Astragalus sp.. . . . . Milkvetch

Chenopodium sp. . . . . Goosefoot

Forbs (cont.):

Comandra umbellata	Pale bastard toadflax
Eriogonum pauciflorum	Eriogonum
Eurotia lanata	Winterfat
Grindelia squarrosa	Curlycup gumweed
Helianthus petiolaris	Prairie sunflower
Hymenoxys richardsonii	Hymenoxys
Lepidium sp.	Pepperweed
Oxytropis sp.	Locoweed
Phlox hoodii	Hood's phlox
Polygonum sp.	Knotweed
Potentilla pennsylvanica	Pensylvania cinquefoil
Sphaeralcea coccinea	Scarlet globemallow
Taraxacum officinale	Dandelion
Thermopsis rhombifolia	Prairie thermopsis
Vicia americana	American vetch

Shrubs:

Artemisia cana	Silver sage
Artemisia tridentata	Big sage
Atriplex nuttallii	Nuttall saltbush
Chrysothamnus nauseosus	Rubber rabbitbrush
Chrysothamnus viscidiflorus	Little rabbitbrush
Gutierrezia sarothrae	Broom snakeweed
Opuntia polycantha	Plains pricklypear
Rhus trilobata	Skunkbush
Rosa sp.	Rose
Sarcobatus vermiculatus	Greasewood